EVOLUTION
FROM NEBULA TO MAN

JOSEPH McCABE.

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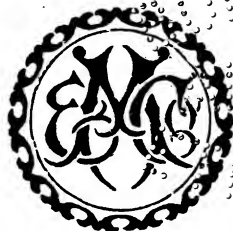THE GREAT NEBULA IN ANDROMEDA

EVOLUTION

A GENERAL SKETCH

FROM NEBULA TO MAN

BY

JOSEPH McCABE

Author of "The Origin of Life, &c. Translator of Fauth, Günther, Haeckel, &c.

Illustrated

NOTE

THE dimensions of this little work will sufficiently prepare the reader to appreciate its scope. It gives no more than the broad outlines of the evolution of the earth and its inhabitants. From the great volume which a score of sciences have co-operated in writing on that absorbing subject it selects only the pages that are most interesting and intelligible to the general reader. These pages it joins into a continuous story, which opens with the mighty cloud of matter that was stirred into giving birth to our sun and its planets, and ends with some attempt to forecast their fate in millions of years to come.

In so brief an account of so long a story only slight reference can be made to the controversies that divide modern students of evolution in regard to the agencies at work. The aim is chiefly to present a panoramic view of the development of the world—especially the world that lies close about us—by a conscientious use of the results of many sciences, and aided by a personal acquaintance during many years with both telescope and microscope. But disputed points will be left open, conjecture plainly stated as conjecture, and the latest theories of importance indicated; so that the reader may be at least slightly informed on the systems—Weismannism, Mendelism, etc.—that now occur in all he may read further on the subject.

LIST OF ILLUSTRATIONS

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EVOLUTION

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CHAPTER I

THE EVOLUTION OF THE IDEA OF EVOLUTION

THE word "Evolution" is so familiar to everybody to-day that it may seem quite superfluous to delay, even for a page, in making its meaning clear. Great scientific truths that startled even the most thoughtful men little more than half a century ago now fall glibly from the lips of the schoolboy. He knows that all the varied animal and plant forms on the earth are more or less distantly related in the family of nature. He knows that the suns that faintly shine on him through billions of miles of space are all running through a long life story, and he may have a general idea of their career from their cradle in a nebula to their grave in the darkness of space. Even if he has contrived to avoid learning this, he knows that the railway engine has had a long development, and that the British Empire was not formed in a day.

But let the reader, if he has had no special training in the matter, attempt to tell himself what he means by evolution. He will soon see that he has by no means the clear and definite idea that he thought he had, and that it is extremely desirable to have at the outset of any study whatever. In point of fact, it has cost learned men some effort to say in a few clear words what is meant by the idea of evolution.

We will, however, not linger in examining definitions of evolution, but will be content to give some shape to the vague idea which everybody now attaches to the word. Evolution does not mean merely a long life of change. Here, for instance, is a tiny worm-like creature that lives parasitically inside another animal. Its ancestors have done so for ages, and the form has been greatly changed during those ages. Yet, instead of evolving, it has done the very opposite. It is an example of what is called "devolution," or evolution turned backwards. If you could imagine a modern locomotive getting amongst a backward people, who fell short of the model each time they made fresh ones, and at last produced something like Stephenson's primitive "Rocket," you would have some idea of change through many generations without evolution. Evolution means advance from simplicity to orderly complexity, from a loose association of a few parts to an elaborate and definite association of many parts, from vague general characters to a number of very definite and particular characters. The original dog was not like any living dog, but had only those features which the present different kinds of dogs have in common. Earlier still was an animal with the features that are now common to the dog, wolf, and fox; still earlier one with the general features of the cat, tiger, and lion as well.

This idea of advance from vague general objects to very definite, complex, and specialised objects is the idea of evolution that we apply to the universe and all it contains. All the plants are specialised descendants of a tiny simple speck of living matter that floated in the primitive ocean tens of millions of years ago. All the countless species of animals descend from a jelly-like speck that was not far removed from the first plant. All the bodies in our solar system are condensed pieces

of a vague mist of chaotic matter that once filled our portion of space. Just as all the countless forms of steam engines to-day have evolved from a kettle pushing a poker with the steam from its spout; and all our national constitutions from the primitive social arrangements of a group of savages.

The universality of evolution implies, of course, that the idea itself was slowly developed, and it is interesting to glance at this before we apply it on a large scale. It is one of the most surprising things in the history of thought to find that the idea of the evolution of the world and the living things in it was held by a great many people more than two thousand years ago. Almost as soon as that most brilliant of the ancient nations, the Greeks, began to speculate on the past history and present nature of the world about them, they felt that this was the key to the mystery of existence. In the energetic life of the Greek colonists in Asia Minor, six hundred years before Christ, a great stimulus was given to thought about the world, independently of the childlike legends of the race. One of the earliest of these thinkers, Thales (who lived about 600 B.C.), declared that all the solid and very varied things in the world about him had grown in the course of ages out of some vague universal fluid; in other words, he thought that water was the primitive element, and all other things " developed "—as we should now say—out of it. One of his pupils, Anaximandes (about 570 B.C.), thought that all living things had come out of non-living slime, and passed through many forms before they reached their present shapes. He even made the perfectly sound point that there was a time when man was a fish. A third member of the school, Heraclitus, held that fire was the primitive element.

As time went on, this vague notion that living things

were not always as they are, but had somehow grown out of simpler elements, struggled nearer and nearer to the truth. In all the fragments of speculation that have come down to us it is, of course, twisted into forms that depart widely from the truth and mixed up with speculations that seem to us grotesque. Nothing else could be expected in that first faint dawn of knowledge. The remarkable thing is that so many correct guesses—for they were little more than guesses, in the absence of systematic observation and experiment—are found amongst the false ones. I will notice only the more interesting points that were added to the original idea as the school continued to dwell in it.

Empedocles (born about 490 B.C.) thought out something like the doctrine of the struggle for life and survival of the fittest, which seems so peculiarly modern. Innumerable forms were begotten in the crystallisation of the primitive elements, he said; of these many perished because they were unfitted to live. A little later Leucippus put forward the theory that the universe is built up of tiny particles, which he called "atoms," because he regarded them as the ultimate and indivisible (*a-tomos*) elements. An infinite number of atoms, of different sorts and sizes, tossing about during infinite time in an infinite space, might produce the things that actually exist amongst the myriads of chance forms they would assume. This eternal tossing at hazard is quite opposed to our knowledge of law in the universe, and we now know that "atoms" are not indivisible; but the atomic theory has played a great part in science and continues to play it, with a modification in regard to the constitution of the atom. Democritus (born about 460 B.C.) gave a firmer and more reasonable shape to the idea of the atomic evolution of the universe, and a century later Epicurus gathered together the speculations

of these leaders of the "Ionic school," to which all the preceding belonged.

But the best and most finished account of the theory is found in the work of the Latin poet, Lucretius, *De rerum natura* ("On the nature of things "). Just as the curtain was falling on the brilliant episode of Greek civilisation, their culture was transferred to Rome, in the century before the birth of Christ. The Romans were great administrators and lawyers, and we are not surprised that in their hands science and philosophy developed no further; but it is in the poetry of Lucretius, a disciple of Epicurus, that we find the idea of evolution in the highest form it attained in the Greek mind. The infinite number of atoms is now ruled by law, instead of tossing aimlessly in the void. They group themselves according to their affinities, and form large and complex bodies. "The earth, the sun, heaven, and the race of living things," are slowly formed out of their orderly combination. First plants and then animals arose out of the earth, "the mother of all things," under the influence of rain and heat; many of the living forms that arose, though they were not the grotesque monsters of Empedocles, were unfitted for life on earth and perished. Men were evolved from non-human animals. They were at first all savages, without speech or social order; and in the development of civilisation they passed from an age of stone weapons to the use of metals, first copper and then iron.

These fortunate conjectures are, we must always remember, mixed up with a larger proportion of crude speculation. With the exception of Aristotle, the Greeks slighted exact observation and were ignorant of experiment; they trusted unduly to philosophical speculation about things. Yet there can be little doubt that if their culture had been evenly developed we should be much

further advanced than we are to-day. Unfortunately, speculations of this kind fell into contempt in Europe, and the night of the Dark Ages settled on the ruins of the older civilisations. Only here and there do we catch a glimpse of the truths that Greece had discovered. It has often been pointed out that St. Augustine, one of the most learned Fathers of the Church, was in some sense an evolutionist. God, he said in his interpretation of *Genesis,* had been content to put "the seeds of things" in the primitive earth, so that the plants and animals had been more or less self-developed. At Alexandria, which became the Athens of the later Greek world, the early Fathers had been in close touch with Greek culture, and these are lingering traces of Greek influence in the new thought. But in later life St. Augustine frowned on all such speculation, and spoke harshly of the best of the Greeks.

In the course of the Middle Ages we find more than one strong thinker, like Scotus Erigena (ninth century) or Giordano Bruno (put to death 1600), attempting to bring speculation back to Greek lines; but it was not until after the full revival of ancient learning that it returned to profitable avenues of research. Greek learning had in the meantime passed on to the Arabs, and their scholars began to develop the more scientific methods of Aristotle, who had fully recognised the value of minute observation. From Arab Spain the new spirit crossed the Pyrenees, and soon such men as Roger Bacon and Albert the Great were laying the foundations of experimental science in the heart of Christendom. When the Renaissance and the Reformation occurred in succession, the hindrances to freedom of speculation grew more and more enfeebled.

In the new and stimulating atmosphere men began again to look out on nature with keen, inquiring eyes,

The narrow limits of the little medieval universe were thrust back indefinitely. The crystal globes that were thought to have hemmed it in were shattered by Copernicus and Galileo, and the stars sank back into profound abysses of space. Before the end of the eighteenth century the idea of evolution was again peeping timidly out of the pages of scientific writers. Buffon, the great French naturalist, very clearly held it in principle, but there were still too many censors in France to permit him to develop it. Rousseau made men familiar with the idea of the social evolution of humanity. In England Erasmus Darwin, born in 1788, boldly advocated development, and anticipated more than one idea of his more celebrated grandson. He noted the unity of plan in all animals, the metamorphoses of animals like the frog or the butterfly, and the changes wrought in animals by artificial selection and climatic variations. These things, he said, pointed to a common descent of all living things from some primitive "living filament."

From the side of astronomy and geology the principle of evolution was being slowly established. In 1755 the greatest of German philosophers, Immanuel Kant, then a young man of more scientific than philosophic temper, had published the germ of the nebular theory—or the condensation of the heavenly bodies out of a thin and far-scattered mist of gaseous matter. His little work attracted no attention, and was in fact completely forgotten for nearly a hundred years. In the meantime the brilliant French astronomer and mathematician, Laplace, impressed the theory on the cultivated mind of Europe by his full and powerful elaboration of it. Since that time—he issued his *Exposition of the System of the World* in 1796—the principle of evolution has had a firm base. His theory has naturally had to undergo a good

deal of modification, as we shall see; but his name is for ever associated with the first great demonstration of the truth of evolution.   Geologists were advancing a little in the rear of the astronomers.   In 1829 Sir Charles Lyell published his *Principles of Geology*, which gave a new extension to the idea of evolution.   Laplace had shown that our earth was originally a huge fragment (or "ring," but modern astronomy does not hold to this) of attenuated matter thrown off by the condensing nebula. Lyell carried the story a step further, and showed that the agencies which we see at work on the face of the earth to-day have slowly put together the belt of solid rock that confines its molten bowels.

The way was being rapidly cleared for Charles Darwin and Herbert Spencer.   The application of evolution to living things was made difficult, not only by the general prejudice arising from traditional views, but by the fact that the great naturalists Linnæus and Cuvier had declared the various species of animals and plants to be unchangeable.   When, therefore, Jean Lamarck began in 1802 to press the idea of biological development, he had an insuperable prejudice to fight.   His most famous work, the *Zoological Philosophy* (1809), elaborated a complete system of evolution through the now familiar forces of heredity and adaptation.   His speculations in detail were naturally crude and premature, but his general work was so well thought out that even one of the modern schools of evolutionists goes by the name of the Neo-Lamarckians.   In his day the opposition was too strong for him, and he died in obscurity. But the principle had now an indomitable vitality, and was breaking out on all sides. Goethe in Germany consecrated and applied it in his immortal works; it was making its appearance constantly in England before the middle of the nineteenth century. I found in an obscure English journal of the

year 1842 (the *Oracle of Reason*) a long and interesting sketch of the genealogy of the plants and animals by one William Chilton.

In 1844 an anonymous work (since known to have been written by Robert Chambers) spread the theory throughout Britain. This work, the *Vestiges of Creation*, had little exact knowledge and much crude speculation; but its author sought to reconcile the new doctrine with religious teaching, and his work stirred up controversy from one end of the kingdom to the other. In 1852 Herbert Spencer began his life-work on evolution with an article in the *Leader* on "the development hypothesis." By this time both Charles Darwin and Alfred Russel Wallace were bringing a wide and exact biological knowledge to bear on the subject, and Darwin had already grasped the principle of natural selection. As early as 1842 he made a manuscript sketch of his theory, and from that time until 1858 he was engaged in building up its structure. In 1858 he was startled to receive from A. R. Wallace a manuscript containing exactly the same theory. A joint paper was read in their names before the Linnæan Society, and the *Origin of Species* appeared in 1859.

We need not attempt to summarise either the familiar contents of the *Origin of Species* or the fiery controversy that followed its publication. In 1863 Huxley boldly applied the principle of evolution to man, in his *Man's Place in Nature*, and Darwin followed with his *Descent of Man* in 1871. Haeckel was spreading the new gospel in Germany with characteristic vigour, and in England Herbert Spencer's successive articles and volumes were extending it over the whole contents of the universe. But the literature of the subject now grows too voluminous to notice. The idea of evolution was fully evolved, and group after group of scholars made it the vital

principle of their research.   Archæologists were slowly
bringing to light the evolutionary story of prehistoric
man; philologists were linking the languages of the world
in genealogical groups; religions, arts, and social institu-
tions were having the same broad light cast on them.
The idea of evolution is now one of the surest guiding
principles of the scientific investigator, and its application
has been traced with considerable success.   What
modifications have been made of the earlier theories, as
our knowledge of nature increased, will appear in the
survey of the more interesting parts of the field on which
we are now in a position to enter.

CHAPTER II

THE BIRTH OF THE SUN AND PLANETS

THE earliest application of the law of evolution to secure a firm groundwork was, we saw, the application to astronomy. At first sight it may seem strange that men should discover the action of the law in bodies that lie millions of miles away from us, or even dwindle into points of light across billions of miles of space, before they were sure of its action in the world immediately about them. But the panorama that evolutionary astronomy now unfolds to us enables us to understand the reason of this singular truth. The animal and plant types that surround us stand out quite distinctly in the economy of nature, and persist unchanged generation after generation. Aristotle and Pliny describe animals just as we know them to-day; the earliest Egyptian inscriptions depict racial types in features that they have in our own time. Experience, apart from the artificial conditions of breeding, seems to be wholly on the side of the unchangeability of species.

It is entirely different in astronomy. A nebula was said by Laplace to be the ancestor of the sun or star millions of years ago, and no sooner were large telescopes invented than the nebula was discovered to be a reality. Many of the white blotches in the heavens that those early astronomers took to be nebulæ did, indeed, prove to be close clusters of stars, but real nebulæ were found in abundance. One of the finest, in fact—the nebula in Andromeda—is plainly visible to the naked eye. As instruments improved in power, as the spectroscope

came to the aid of the telescope, and the camera brought
further aid, the real nebulæ were sorted out, and were
found to run into hundreds of thousands. Further, they
were found to be in every stage of evolution, from vast
even stretches of smoke-like matter to objects that stand
out like gigantic "catherine-wheels" on the inky back-
ground, and on to nebulæ that have all but finished their
condensation into stars. Then we find clusters of stars
(like the Pleiades) that reveal on the photographic plate
faint wisps and patches of nebula lingering amongst
them, telling of the birth of the cluster æons ago from a
vast cloud of gas. Finally, the stars themselves turn
out to be of different ages. Some are rising with titanic
energy from their nebula-cradles; some are pouring the
fiery energy of full development over incalculable reaches
of space; some are sinking slowly to the blood-red that
tells of old age; and some are dead, dark bodies whose
long life-history is over.

This is the peculiar value of the facts of astronomy
for the student of evolution. All the chief stages of the
story are illustrated in the heavens, and can be verified
night after night. A close examination of even a
single district in the sky—say the district of Perseus
and Auriga—will reveal all the links in the chain of
astronomical evolution. The immeasurable vastness of
space compensates for the flow of time. Our telescope
sweeps across a field of at least 4,000 billion miles, and
none can say how much more, from horizon to horizon.
The past lives in that incalculable present. The hundred
million inhabitants of our stellar universe exhibit to us
the phases through which the star passes from the faint
luminosity of the nebula to the solid dark extinct sun.

Hence we quite confidently begin the story of the
development of our sun and its planets from a nebula.
The "nebular hypothesis," as it is still called, is an

interpretation of world-development that has passed beyond the stage of hesitation. Stars or suns are born of nebulæ, and, under certain conditions, will return to nebulæ. The solidification into globes and the clothing of some of those globes with living mantles are episodes in this stupendous rythm of movement from nebula to nebula. Our task is to trace the condensation of nebulæ into solid bodies, and see what modifications recent research has made of Laplace's original suggestion.

In the first place, then, let us get our starting-point clearly defined. A nebula has been so commonly described as a "fire-mist" that most people insist on conceiving it as a gigantic mass of white-hot matter, thinned out far beyond the thinnest gas, and spread over an incalculable space. The modern astronomer has strong reason to think that a nebula need not be, and at some stage probably is not, incandescent at all. We believe that there are dark nebulæ as well as visible ones ; just as there are dark stars as well as visible ones. Further, when the nebula is luminous, its light may be due to electrical or radio-active conditions. Indeed, there are now distinguished authorities who do not take a vast outstretched gas as the starting-point of our system at all. Sir Norman Lockyer has persuaded many that the chaotic diffused mass, out of which our sun and its planets have condensed, was a swarm of innumerable meteorites—those blocks of metal or stone that swarm erratically in space, and so often perish above us as "shooting-stars."

More recently still a third alternative has been put forward, and must be noticed here, whatever its ultimate fate may be. A distinguished American student, Professor Chamberlin, a geologist who claims that even the earlier chapters of the earth's story fall within his province, has conjectured that the diffused mass of

matter was neither atoms of gas nor meteorites, but something between the two.   Our solar system, he says, was formed from a spiral nebula, and the nebula consisted of "planetesimals," or particles of liquid or solid matter in a finely divided state.   For our elementary purpose this difference in the constitution of the nebula matters little; but it involves some very important differences at a later stage, which we will notice in due course.*

We start, therefore, with the material of our solar system dissipated over several thousand million miles of space.   To-day it is collected into a great ball (the sun) 860,000 miles in diameter, and a few smaller spheres from 3,000 to 87,000 miles in diameter.   At one time it was scattered loosely over the whole space occupied by our solar system (5,500 million miles across) and far out into adjoining space.   Whether it was in the form of gas, or planetesimals, or meteorites—or any two of them in turns—we may leave open.   No doubt it passed through many phases, and the strongest probability is that it consisted at first—as all the great irregular nebulæ do—of gas.   In any case the general laws of its condensation into worlds remain.

But many a reader will refuse to go further until something is said of the origin of the nebula itself. Here again the very magnitude of the universe comes to our assistance.   Nebulæ have been born before our eyes in the heavens within the last few years.   On the night of the 21st of February, 1901, a very bright new star appeared in the constellation Perseus, where no star had been visible the night before.   When we learn that this

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* The planetesimal theory is fully worked out, and contrasted with the other theories, in Chamberlin & Salisbury's *Geology*, vol. ii.

body was at least 500 billion miles away from the earth
—that is to say, so far away that it would take 1,500
million years to count the miles, at one mile per second
—we begin to realise what this means. It means a
sudden conflagration of a most stupendous character;
you have some idea of it if you imagine a sun to be
made of petroleum and suddenly fired. Astronomers
watched it with great curiosity for months. The blaze
slowed down, flickered and flared, and at last went again
below the range of visibility. But all during the winter
a little cloud of luminous matter was creeping out from
either side of the point of light. At the end of six
months the cloud was "no bigger than a man's hand"
in the large telescope—very much smaller, in fact—but
astronomers knew what that meant, having regard to the
distance. It was several billion miles in extent: its
"creeping" meant a motion of more than 100,000 miles
a second. A new nebula was given to the universe—if
we may set aside the opinion of a few that it was the
sudden lighting-up of a dark nebula. I said that a nebula
was formed under our eyes in 1901. It really happened
under the eyes, or over the head, of Napoleon I; but the
conflagration was so far away that, though the waves of
light were hurrying with the message across space at the
speed of 186,000 miles a second, it took them 99 years
at least to bring it to the earth.

What was the cause of the catastrophe, and therefore
of the birth of the nebula? If we know this we have a
sufficient suggestion to offer to those persistent people
who refuse to go on until they know where *our* nebula
came from. We do not know definitely, but we know
several ways in which it might arise. Many observers
thought—Sir R. Ball and others still think—that two
dead stars came into collision. If such a thing—even a
"grazing" or partial collision—did happen, it would be

enough, not merely to liquefy, but to scatter the material
of the colliders in incandescent gas over billions of miles
of space. Few stars travel at less than 20 miles a
second, and the conversion of this motion—in the case
of such enormous masses—into heat would be quite
enough. Most astronomers, however, do not think
collisions probable. They believe that the dead (or
faint) star ran into a dense and gigantic swarm of
meteorites, or even into a dark nebula; or some internal
convulsion may have torn it open and scattered its
white-hot entrails over space.

At all events, here was the birth of a nebula, and our
nebula and all those we see may have arisen in any one
of these ways. There is, in fact, no " beginning " to the
story of astronomical evolution. Some have said that,
as all the energy we know tends to be converted into
heat, there will come a time when all motion of
masses will cease, and so there must have been a time
when it began. But this assumes a knowledge on our
part of the cosmic machinery which we certainly do not
possess. Not until we have a fair command of the
ultimate sources of energy—those strain-centres in ether
which finally make up the universe—can we say whether
or no the heat is capable of being reconverted into energy
of movement. Astronomy points to no beginning or end,
and it is idle to speculate on a point that is wholly outside
the range of the scientist. Nebulæ condense into solar
systems; dead stars return to nebular life. Mr. Gore
calculates that on the average probably two such
resurrections could be observed every year.

For our purpose we start with the cloud of diffused
matter that once spread out far beyond the limits of our
solar system, and has slowly condensed into the spheres
that compose that system. We may take it to have
been initially a gas (like the new nebula in Perseus), and

leave open the question whether it passed through a
meteoritic phase. The broad principle is that, under the
influence of gravitation, the infinitely loose and scattered
particles have been brought together into a liquid and
then a solid condition. Watch the schoolboy taking up
the loosely-knit snow and forcing it into a hard ball.
So vast hands have closed round the flocculent matter
of the nebula, and squeezed it into balls. We do not
know precisely what gravitation is. Certainly it is not
an *attraction* of one particle by another, as even Sir
Isaac Newton pointed out. Most likely it is the pressure
of the environing ether on every side of the great nebula,
forcing the particles together.

The more difficult question is how the condensing
mass came to leave behind the smaller masses, which
formed the planets, before it shrank into the sun.
Laplace's theory was that as the mass drew inwards and
at the same time revolved on its axis, there repeatedly
came a time when the fringe of matter at the outside
felt an equal pull towards the centre (from gravitation)
and from the centre (by the centrifugal force of the
revolution). So, time after time, a broad ring of matter
at the edge of the disc was detached. This matter
would settle round any thicker spot in the irregularity of
its texture. The ring would be slowly gathered into a
ball, and would be bound to continue the original revolu-
tion round the centre of the system. Thus, one by one,
beginning with the outermost, the planets were formed.
As they in turn were small nebulous masses, they would
cast off rings as they condensed, and so form moons or
satellites.

There are astronomers who still think this system
tenable, with some modifications. The majority, how-
ever, find a grave difficulty in the retrograde motion of
some of the bodies in the system, and do not think the

ring-theory adequate. Again the great object-lesson
of the heavens comes to our aid. Of the 120,000 nebulæ
that we know, about half show what is called a spiral
structure. Vast arms of luminous matter stretch out
into space, in circles or semi-circles, from the centre of
the nebula. These, moreover, are the nebulæ that seem
to be in process of formation into worlds. An incan-
descent gas gives, when its light is analysed in the
spectroscope, one or more vertical lines of light. An
incandescent liquid or solid gives a continuous rainbow
band of colour (unless vapour intervenes). Now the
great irregular nebulæ, like the beautiful and immeasur-
able one in Orion, have a gaseous spectrum, and seem
to be comparatively at rest. The spiral nebulæ—the
vast nebula in Andromeda, that you can see right over-
head on a winter's night with the naked eye, the fine
specimen in Canes Venatici, etc.—show the spectrum of
a more condensed condition. It is irresistible to think
that these spiral nebulæ are the second stage, and that
the planets or attendant bodies of the central sun will
form from the great arms of the spiral. They are
irregular in texture, thus offering centres for condensa-
tion. In some cases the material of the arms is already
gathering into balls: in others the arms seem to have
shot right out from the central sun.

It is probably wrong to seek one type of formation for
all the systems in the universe. They vary enormously.
The ring-system may have been verified in some cases.
The spiral seems to be the general mode of detaching
masses from the shrinking body. In other cases the
detachment may have taken place in yet other ways.
Our moon is now very largely believed to have budded
out at one end of the earth (like the knob at the end of
a lemon) or broken off in a tidal wave in its early plastic
stage, when it rotated much more rapidly than it does

now. Nebulæ, no doubt, in some cases (compare dumb-bell nebulæ), split in two from the speed of rotation. In whichever way it was, the original nebula of our system went on contracting, spinning round on its axis, and casting detached masses off to form planets. We cannot enter here into the dynamical considerations by which experts follow the phases of contraction. They show that the matter would in time arrange itself in the form of a disc, thus the detached planetary masses would lie in or about the same plane. They show that the very fact of condensation would bring about that turning on the central axis, which accounts for the revolution of the planets round the sun. They show that the spiral form is a natural consequence of the rotation, as the inner particles will revolve more rapidly than the outer ones. But for these dynamical arguments the interested reader must consult specific works on nebular evolution, like Sir Robert Ball's *Earth's Beginning*.

In outline, the first chapter of our story is now fairly clear. It opens with a great nebula, luminous or dark, with a girth of at the least 20,000 million miles. Under the forces of gravitation, or the pressure of the ether of outer space, its particles push inward toward the centre. The irregular mass rounds itself more or less, turns with increasing speed on its axis, and thins out into a plate or disc. Its even texture breaks up, and the matter gathers into vast arms flung out spirally from the main centre-mass. Thousands of small bodies may crystallise out of the mass, but the greater number will be absorbed or thrust into the larger fragments. In the end nine smaller masses (assuming that the planetoids are frag-ments of a disrupted body) will circle round the pre-dominant mass that has gathered together at the centre to form the sun. Whatever the temperature at first, the collisions of the swiftly moving particles will, as they

approach closer, generate an ever-increasing heat. The smaller the mass, the more quickly will the work of concentration proceed. Each planetary mass, having cast off its own fringe of arms or rings or tidal bulges, will round into a ball of incandescent matter with a temperature of possibly 10,000°C. at its surface. Eight or nine small suns will course round the parent mass, still a hazy half-concentrated nebula. The smallest bodies—the moons—will first run through their period of brilliancy, sink to a dull red, and at last have their molten interior hidden under a solid crust. One by one, according to size, the planets will run the same course : first Mercury (2,946 miles in diameter), then Mars* (4,172 miles), then Venus (7,894 miles), and Terra (7,926 miles). Jupiter and Saturn seem not yet sufficiently cooled at the surface to support oceans ; dense belts of clouds envelop their gigantic frames. The sun, 324,000 times heavier than the earth (or 2,000 trillion tons in weight), is still in the throes of condensation. Whatever share radium may have in its outpouring of heat, the simple condensation of its mass would sustain its enormous temperature (probably 7,000°C. at the surface, and higher within) for millions of years.

To the future evolution of the sun and its planets we will return later. At present we must follow the direct thread of our story, and trace the development of that one of the arms or masses detached from it that became our planet. Before we do so, however, two further points must be briefly touched in this chapter.

In the first place it will be asked "when these things were." Can modern astronomers give us some idea of

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* Assuming that the planets were not formed at long intervals. I must point out that the "planetesimal" theory denies this incandescent stage, and assumes a less violent fall of its particles into the planetary and solar masses.

THE MOON

the time that has elapsed since our parent nebula began its fateful process of condensation ? Here we enter upon precarious ground, and it will be enough to quote a few opinions. How long the formation of the *crust* of our earth may have taken is a different matter, that we will consider later. At present we have the broader question that faces the astronomer and the physicist. It is well known that Lord Kelvin made a careful calculation, based on the sun's expenditure of heat, and came to the conclusion that the physicist could not allow more than a hundred million years at the outside for the development of our solar system. Many geologists and biologists stoutly maintained that this would not suffice for the development even of the earth's crust and its living inhabitants, and for years there was a warm controversy. The end of it is curious, and contains a good moral for controversialists on these abstruse issues. While geologists and biologists have, as we shall see, greatly moderated their demands, the physicist has suddenly been compelled to offer them an almost indefinite period.

The discovery of radium has entirely altered the situation. Lord Kelvin proceeded on the supposition that the heat of the sun was due almost entirely (allowing for the infall of meteorites) to condensation, in the way I described above. But the discovery that heat is provided out of the very interior of the atom affords a new and formidable source of heat. In the atom of radium about a quarter of a million electrons are organised in a system of minute points (or centres of energy) whirling round at an inconceivable speed. As the atom breaks up, they fly off at a speed of at least 100,000 miles a second, and are the most interesting element in the now familiar emanation from radium (and other substances). The heat evolved in this process is $3\frac{1}{2}$ million times

greater than the heat given in any ordinary chemical combination of atoms. It would—Le Bon calculates— take 340,000 barrels of powder to send off a bullet at the rate at which the electrons fly out of the atom of radium. Here is a source of energy so appalling and unexpected that Lord Kelvin long refused to credit the facts. We have only to suppose that there are large quantities of radium in the sun, and the whole problem of the continuance of its heat is changed. Many astronomers (like Meyer) maintain that there are millions of tons of radium in it—that the terrific electric storms it sends to us, especially from the margins of its "spots," are radio-emanations. However we may esteem the evidence, the possibility remains, and the age of the sun may be indefinitely greater than was supposed.*

It is now therefore quite useless to conjecture, on the old lines, what the age of our system may be. I will, in conclusion, merely quote the words of one most competent to express an opinion on the subject, Sir G. H. Darwin. The birth of the moon from the earth is, we saw, an episode in the life of our solar system, that dates some long time after the first movement of the nebula (or meteorites). Now, Sir G. H. Darwin is responsible for one of the most commanding theories on the origin of the moon, and in his presidential address to the British Association in 1905 he says in regard to the remoteness of that event :

"If at every moment since the birth of the moon tidal friction had always been at work in such a way as to produce the greatest possible effect, then we

* It is sometimes objected that, as the life of an atom of radium is computed to be only about 2,450 years, there cannot have been radium in earlier times. But it may be forming in the sun as constantly as it is breaking up. It is said—though some deny this—to be evolving out of uranium under our eyes.

should find that sixty million years would be con-
sumed in this portion of evolutionary history. The
true period must be much greater, and it does not
seem unreasonable to suppose that 500 to 1,000
million years may have elapsed since the birth of the
moon."

The point is of little importance, though it has a
fascination for many people, and we will pass on to the
second subject that it is proper to touch upon before we
take up again the chief thread of our story. We have
seen, in outline, the birth of our solar system from a
nebula. To what extent may we apply that scheme to
the other suns of our stellar universe?

That the "stars" are "suns" now needs no emphasis.
The same elements, in greater or less number, in one or
other form, enter into their composition. Some are
smaller, some thousands of times larger (or its equiva-
lent in brilliancy) than our sun. More than a hundred
million of them make up the system to which our sun
belongs. Those we can examine are travelling at an
average rate of 21 miles a second; a few of them at 100,
150, and even 250 miles a second. Few of them ap-
proach within 100 billion miles of us. The greater
number are more than 1,000 billion miles away, and
elude the wonderful measuring devices of the astronomer.
Millions lie so far away that, though they are doubtless
comparable to ours in size and brilliancy (150 times as
brilliant as the lime in the limelight, and many of them
much more intense), they take seven or eight hours to
register a faint point of light on the most sensitive
photographic plate in the larger telescopes. Hour after
hour their waves of light are falling on the plate at the
rate of 700 billion *per second*, yet they take so long to
impress a tiny dot on a plate that would register a land-
scape in a fiftieth of a second.

But the evolutionary aspect of this wonderful universe is, perhaps, more impressive still. We have seen that the objects in it illustrate every phase of growth. Some 120,000 nebulæ (calculated) show the earlier stages. Dark stars, of which many are positively known, and the total number is suspected to be very great, tell the end of the story—the fate of our sun. The nebulæ range from apparently motionless objects—though nothing can be absolutely motionless in the universe—to great spiral structures that express an infinite constructive energy. In the case of the nebula in Orion a dark patch eats into the heart of the filmy white cloud, and a system of six stars is spread over the vacant space; it seems clear that the missing nebulous material has gone to the making of these stars. Then there are nebulous stars, in which the light of the growing centre struggles through as yet uncondensed masses of gas.

The spectroscope carries the story further. The various colouring of the stars has always attracted interest, but it remained for modern science to reveal its meaning. Broadly speaking, the meaning is simple. A bar of iron is hottest when it is white, cooler when it is yellow, and still cooler when it is red. So your white or bluish-white star is in the prime of life, your red star sinking into old age, and your yellow star either before or after its prime. But the astronomer does not rely on this crude test of age. The spectroscopic analysis of their light tells him not only how fast they are travelling and of what material they are composed; it also gives most valuable indications of the condition of the elements in the star, and therefore of its age. There are serious difficulties with some classes of stars, into which we cannot enter here; but a sufficient number have been classified to give us an idea of the life of a star. At first its light shows a mass of metallic vapours at what we

may call a moderate temperature for the stellar world. The gases of the nebula or the meteorites of the great swarm—whichever theory one follows—are gathering closer together, and the temperature is rising to thousands of degrees from the colossal friction. In the hottest stars the process of condensation has produced its maximum heat, which may safely be conceived at something over 10,000°C. The chemical elements in it are found to be actually dissociated in that appalling furnace. At a later stage the electrons close again into atoms; the various metals re-unite, and a layer of molten metal thousands of miles thick forms the surface of the star. The vapours of the metals lie above this layer, and more thousands of miles of red-hot gas, with a cooler atmosphere hundreds of thousands of miles deep envelop the whole. As the loss of heat continues to be greater than the production of it, the cooler vapours thicken round the molten photosphere. Great black patches (sun-spots—in reality wide oceans of cooler vapour in which our earth could swim freely) appear on the disc. The light to a distant observer sinks from white to yellow, and as the vapours grow denser, to red. Dark-red suns, of which we know many, point to a further stage in the choking of the luminous centre. In time, as we shall see in the last chapter, all the vapours will turn to liquid, the liquid to solid, and a dark crust will form round the condensed remainder of the nebula.

The only difference that we need note here in the case of our sun is that it is a solitary star. A comparatively small nebula has crystallised into one great luminary with a number of much smaller satellites. This seems to be an exceptional occurrence. Double stars seem to be the rule in the heavens; triple stars are common, and even much more complex systems known. The 2,326 stars of the Pleiades cluster seem to have formed, in the

main, out of one vast nebula. The 5,000 stars of the beautiful clusters in Hercules or Centaur appear to have a similar origin. It would at present be much too hazardous to extend the idea further. It is a fascinating speculation to imagine the whole 120 million suns of our system as the outcome of a colossal nebula, but such speculation has no firm grounds. At present the facts point to the separate life story of star after star within that system. Here and there in it are the clouds of matter that will one day be worlds: here and there are the dead worlds that await regeneration. And on one little ball, circling round a somewhat middle-aged sun near the centre of the system, we intelligent beings look out on the mighty drama that is being played around us. But it is now time to return to the rounding of our terrestrial fragment of the nebula into a planet, and the great processions over its surface that have culminated in the appearance of humanity.

CHAPTER III

THE STORY OF THE EARTH

THE first phase in the story of the earth is, then, a large mass of semi-gaseous, semi-liquid matter that has been detached in some form from the condensing nebula. It consists broadly of the same material as the other bodies that will make up the solar system, and is subject to the action of the same forces. Let us take it as one of the incandescent arms that reaches out spirally from the centre, and is gradually cut off altogether. The inexorable pressure of ether will not permit it to remain spread out in its thin condition over hundreds of thousands of miles of space. Some thicker knot, as we may conceive it, in the fiery cloud becomes a centre of gravitation, and the outstretched filmy mass slowly gathers into a ball. There is nothing to arrest the movement round the centre of the nebula which it had as part of its structure, and the great ball now circles rapidly round the parent ball.

Still the enormous pressure of ether—the reader will remember that we are taking this, provisionally, as the source of gravitation—crushes the ball closer and closer together. Every particle in it is oscillating rapidly, and collisions between them increase as they are forced within a smaller space. The temperature of the mass rises until it reaches an incandescence far surpassing anything that we can reproduce. Assuming that the detached mass reaches in its development a temperature at all corresponding to that of condensing stars, there would be a phase of evolution of great interest.

In the hottest stars, as we saw, the heat is so great that the chemical elements are dissociated. Modern physics has taught us to regard each atom of matter as a complex system of still smaller particles. Take the smallest and lightest of them all, the atom of hydrogen —of which there are 36,000 billions in a cubic millimetre of that gas (the size of a small pin-head)—and imagine it magnified to the size of a large ball. We should find it to be composed of about a thousand tiny particles, at enormous distances from each other relatively to their size, circling round within the limits of the atom at a speed of at least 100,000 miles a second. An atom of oxygen would contain about 16,000 of these revolving particles; an atom of mercury would be an intricate system of 200,000; an atom of radium would be larger still. These "electrons" are generally regarded as strain-centres, possibly of a whirlpool character, in the mysterious ether that fills the whole of space, and is thus gathered up into the more ponderable masses. What forces cause the strain-centres, and what forces link them together into atoms, we do not know. But the evidence of astronomy seems to point to a dissociation or loosening of these atomic systems in condensing nebulæ. Up to a certain point the condensation generates heat more rapidly than it can be radiated away. After that point the production of heat decreases, and the condensing mass slowly cools. As it cools, the electrons draw closer together once more, and the atoms of the different chemical elements make their appearance—first the lighter gases, with simple systems of electrons, and on through the scale to the heaviest elements.

In the story of our earth, therefore, one of the first phases would be the evolution of our familiar chemical elements. The heavier metals would sink toward the centre, the lightest gases hover about the fringe of the

condensing mass, and the heavier gases and vapours would rest between the two. A miniature sun would be the outcome of this arrangement. Above the ocean of molten metal floated the various gases that would one day form the ocean and the atmosphere, holding in them masses of carbon and different salts. They would to-gether form an atmosphere with a pressure on the molten planet 250 times as great as that of the actual atmosphere, and the intense outpouring of heat into space would cause storms that would lash up the molten metal in fiery eruptions and send out the red-hot atmosphere in gigantic flames. This is merely to say that our earth passed through the phase in which we find the sun to-day.

The next chapter of importance in the story of the earth was its giving birth to the moon. Since it was a small nebula, or semi-nebulous body in a state of condensation, it may be imagined as parting with masses of its material, as its own parent-nebula had done. But there was now a new force at work: tidal action. The vast mass of the sun, 92 million miles away, must have had on the liquid earth the effect which we see the moon to have to-day on its liquid oceans. Our earth was then rotating on its axis—the very process of cooling would lead to this rotation—five or six times faster than it now does, and a great bulge or tidal wave was raised at the point opposite the sun. Under the enormous strain on the liquid planet, a mass of 73 trillion tons was detached from it, and continued to circulate round it at the original speed. This mass of matter rounding into a ball in the familiar way, moving slowly out until it reached 240,000 miles from the earth, revolving always, but with increasing slowness, round the parent earth, is the solidified sphere to which we give the name of the moon.

Thus we have in modern astronomy, the first two pages in the story of the earth : first the incandescent phase and the formation of our chemical elements, then the birth of the moon.   We have now to trace in greater detail the transformations that gave us our planet from the small, fiery mass of hundreds of millions of years ago.

That the story was essentially one of cooling needs no emphasis.   Surrounded on all sides by the absolute cold of space, the planet shed its heat prodigally about it. That this cooling would lead of itself to the rotation of the planet on its axis is proved by mathematical considerations into which we cannot enter here.   That, further, the heavier elements would sink deeper into the mass and the lighter elements remain at the fringe is a simple consequence of gravitation.   But this prepares us fully for the succeeding phases of development.   The time would come when the liquid incandescent ball would lose so much of its heat that a skin or scum would begin to form on its surface.   One must not imagine the formation of the crust of the earth as a tranquil and even freezing of the surface such as we observe on the pond in winter, or even as the cooling of a vessel of molten iron.   Titanic energies convulsed the mass of the molten planet ; tidal action raised its responsive wave as long as this was possible ; and tornadoes in the heavy atmosphere lashed and tore the forming skin.   For ages the new film would struggle with the enormously high temperature below and the storms above ; it would fall in slabs or masses, as it formed, deep into the liquid mass. There are authorities even who think that the solidification must have begun at the centre.   But the general feeling is that a film cooled first at the surface.   It would crack like the film on a basin of cooling paste, and its great fragments sink some distance below the surface. The skin of the earth would be too tight for its body in

that early stage, and volcanic eruptions through it would
be a constant occurrence.

After ages of this conflict of solid scum and a
refractory liquid fire, sufficient solid matter would be
formed to encircle the entire globe. A crust of solid but
white-hot rock would now confine the fire below, with
constant eruptions through it to ease the pressure. No
water could settle on it, and the tempestuous atmosphere
lay heavily upon it. Lower and lower sank the tempera-
ture of the crust, as its heat radiated into space. A
distant observer would see the little white star turn
yellow, then red, and at last, when the temperature sank
to 500°C., lose its light altogether, and henceforth be lit
up only from the central luminary. Later the great
masses of oxygen and hydrogen, that had combined into
molecules of water in the atmosphere, began to settle on
the crust. In the enormous pressure of that primitive
atmosphere water could lie as liquid on the surface
at a much higher temperature than now, and a new
struggle of the elements would ensue. The heated crust
would send the water hissing back into the atmosphere
in clouds of steam, but its heat would now pass away
more rapidly, and the contest would be comparatively
short. Before long a boiling ocean would cover nearly
the whole of the earth's crust, and above this was an
atmosphere still fifty times heavier than the atmosphere
of to-day, because of the great volume of carbonic acid
gas that it contained.

Thus we get the triple zone of matter that encircles
our planet—the lithosphere, or girdle of rock; the hydro-
sphere, or belt of water; and the atmosphere, or mantle
of respirable air. Naturally, their features were very
different at that remote date from those they present
to-day, and it is very important in view of the later
chapters to bear well in mind the physical evolution of

our planet. The first solid crust that formed on the molten earth is probably nowhere accessible to-day. In most parts of the earth it is buried under the stratified rocks, or the layers of sand, mud, etc., that have been subsequently worn off the face of the earth and deposited in seas and lakes. Where we have igneous rock at the surface—granite, basalt, or other rock that is clearly a cooled mass of molten matter—we have most probably (in most cases quite certainly) the outcome of later eruptions from below the crust. This is, at all events, the general feeling of geologists. Moreover, there is firm ground for thinking that the primitive crust was spread fairly evenly over the surface of the planet. That it would have nothing like the evenness of a sheet of ice goes without saying. It was formed in an age of convulsions, and after a titanic struggle with the up-heaving forces below it. But there were none of those large ranges of mountains that later, as we shall see, puckered and crumpled the crust into gigantic folds, and by far the greater part of the existing continents has been raised above the level of the water subsequently. The aspect of the earth would probably be at first one of an almost continuous ocean, without the abysses we know in it to-day, broken by comparatively small ridges or islands, round the fringes of which the boiling ocean raged furiously. The withdrawal of the enormous weight of the oceans from the atmosphere, as the water settled on the crust, would have a marked effect on such dry land as there was. It would be relieved of the earlier pressure of about 5,000 lb. to the square inch, and would yield more easily to the pressure from below. Volcanic action on a colossal scale would thus greatly enlarge the size of the first island-continents.

But the atmosphere, though relieved of its vast quantities of steam, would still be much heavier, denser,

and hotter than it now is. All the carbon dioxide that would go to the making of the great forests of a later date, and much that would be absorbed in the rocks, was then held in the atmosphere. The rays of the sun (such as it then was) would hardly be able directly to penetrate this dense shell of cloud and gas; but, on the other hand, the heat that reached the surface could with difficulty radiate again into space. Long after the ocean had cooled, long after heat ceased to reach the surface from below (as it did cease at an early geological period) the earth had a very high temperature from pole to pole. Professor Sollas does, indeed, raise the speculation whether, as the sun's rays could so little penetrate the atmosphere, the primitive ocean, after it cooled, may not have been entirely frozen until the air was sufficiently cleared to admit the sunlight. For reasons into which I cannot enter here, I prefer to suggest to the reader to follow the general view of the earth as having, until millions of years later, a very high and almost uniform temperature.

One other alternative must, however, be noted before we proceed. We saw that a recent theory of the formation of the earth does not admit the initial incandescence of our globe. This "planetesimal theory" of Professors Chamberlin and Salisbury supposes a less violent aggregation of the "planetesimals," or tiny particles, to form the earth. Condensation would, of course, generate a considerable heat; but they suppose that this occurred in the interior of the planet, and only showed at the surface in the escape from below of molten lava. The atmosphere might consist of volumes of gas making its way upward through volcanic vents and porous strata, and the water might be formed underground and settle on the surface long before the planet was fully formed. This interesting speculation has as yet found little

favour, but as the main grounds for wishing to substitute it for the accepted version are dynamical it cannot be closely examined here. There does not seem to be sufficient reason for departing from the general teaching of geologists which I have summarised.

From this point onward the story of the earth, apart from its living inhabitants, is mainly one of the wearing down of the rocky crust by ice, water, and other disintegrating agencies, the deposit of the rubbish in vast layers at the bottom of the sea and lakes, the reconversion of the stuff into rock by the pressure of hundreds of thousands of tons of water, and the upheaval of the new-formed rocks to the surface by the slow rise of parts of the crust by pressure from below. The elements of geology are so widely known that we have here to do little more than briefly sketch the larger changes through which the face of the earth passed in order to attain its present aspect.

At the beginning of settled geological history, during what is called the Cambrian period, large masses of land had emerged from the ocean in the northern hemisphere. The region about the present great lakes of North America, the region about the Baltic, and part of Siberia seem to be amongst the oldest parts of the earth as we know it. On these broken and low-lying lands the torrential rains fell with destructive action, and the bed of the ocean round them filled with the debris that went to form the earliest stratified rocks. But as the water wore away the land, fresh tracts emerged from the ocean. At an early date a continent seems to have stretched (so Suess assures us) across the site of the present North Atlantic Ocean. Parts of Eastern North America, Greenland, the Hebrides, and most of Scandinavia, seem to be parts of that real lost "Atlantic" of earlier ages. Some authorities think that the earth had assumed

A SIMPLE GEOLOGICAL SCALE

Epoch	Period	Relative age	Types of animal life that appear
Quaternary (actual)	Holocene Pleistocene	years 500,000	Neolithic & modern man. Paleolithic man.
Tertiary	Pliocene Miocene Oligocene Eocene	5,500,000	Ape-men of Java. Anthropoid apes, apes, horse, camel, hog, elephant, ox, sheep, rhinoceros, etc. Lemurs, early horse, whale, etc.
Secondary	Cretaceous Jurassic Triassic	7,200,000 3,600,000 2,500,000	Toothed birds, bony fishes. Crab, higher insects, crocodile, flying reptiles, archæopteryx. Monotremes and marsupials.
Primary	Permian Carboniferous Devonian Silurian Ordovician Cambrian	} 9,000,000 8,000,000 5,400,000 5,400,000 8,000,000	Reptiles. Amphibia. Fishes—elasmobranchs, dipnoi, and ganoid. Insects, ostracoderms, cephalopods. Rhizopods, sponges, corals, worms, crustacea, hydrozoa.
Archæan	Pre-Cambrian	indefinite	

NOTE.—The above table is simplified for the purpose of this work. The age is assigned approximately (from the thickness of the strata) on a scale of fifty-five million years for the stratified rocks.

something like a pear-shape during its plastic period, and this would lead to the emergence of the land in the northern hemispheres, and a predominant gathering of the waters in the southern. With the later collapse of a large part of the northern hemisphere, the balance would be largely restored; but the curious tendency of the continents on the actual map of the world to run to a point southwards might find some explanation on these lines. That, however, is a precarious conjecture, and the feature is still very obscure and variously interpreted.

It would be unprofitable and somewhat monotonous to follow our geologists—I have chiefly consulted the latest editions of Suess, Lapparent, Geikie, Le Conte, and Chamberlin—through the vast series of changes in the earth's aspect which they reproduce for us. I will select only the points which it will be most useful to bear in mind when we come to deal with the evolution of living things.

For several million years the ocean and the rains wore away the early masses of land, which continued to rise, with occasional depressions, from the depths of the sea. By the end of what is called the Silurian period large continents were just underneath, or peeping out above the level of the waters. Low-lying continents, with broad and uncertain shores, relieved the monotony of the ocean, and over all brooded the heavy atmosphere that kept off the bright sunlight. The air was probably poisonous, from its quantity of carbon dioxide, to animals such as we now have; nor does the evolution of animal life seem yet to have reached the stage of land-life. Some geologists imagine the swampy continents as covered with large and primitive plant-growths, but the evidence is, as we shall see, too scanty to justify us in dwelling on that conjecture. The ocean itself certainly abounded in life of all kinds up to the level of the fish.

After the Silurian period are two of great interest in regard to the story of evolution. The Devonian period, which immediately followed it, witnessed the formation of the first great mountain chains and the first system of lakes. At the beginning of the period the land rose slowly into mountain ridges in parts of North America and in Scotland and Scandinavia. The cause of the formation of mountain chains has been usually described as a crumpling of the earth's crust on account of the shrinkage of the inner body of the planet. At its first formation the skin would tend to be too small for the earth's body. It would crack into great slabs and sink in the molten mass. After the cooling of the body had proceeded for some further millions of years, the rigid skin, unable to adapt itself to the shrunken body, would shrink into folds and creases. One may recall the wrinkling of the skin on the attenuated frame of an old man. Imagine the skin wrinkling *outwards*, instead of *inwards*, and one has a good idea of the general conception of the rise of mountain ridges. This facile theory has, however, been called in question of late years. Professor Sollas, for instance, believes that the rise of the crust into mountains is rather connected with the laying of tons of sediment on the floor of the ocean. The river system of England is carrying, year by year, thousands of tons of matter off the face of the country, and depositing it on the floor of the sea. The deposit off the coast of America is far greater. After two or three million years of such deposition there will be a terrific burden pressing on the crust under the ocean, and a corresponding relief of pressure on the land. The result will be a displacement of rock from below the deposited strata and toward the land. The pressure of the crust of the earth is so great that at five miles from the surface the rocks are probably plastic, and would flow

toward the land surface to compensate the increased burden. This would be met by a stubborn resistance, and in consequence a vast mass of rock in the shore region would be slowly lifted up above the general level, and form a mountain ridge. A glance at the map of America, showing the great chain of mountains along the Pacific coast, will at once provide an illustration of the theory. The shrinkage of the earth and necessary crumpling of the crust is not, of course, called in question; but the additional theory gives a more satisfactory idea of the formation of mountains.

This process, however it be conceived, began in the Devonian period, and gave us our oldest hills. The greater mountain chains belong, as we shall see, to a very much later date. But the Devonian period was also characterised by a gradual depression of the crust at the continental surfaces, so that great arms of the sea penetrated inland, and ultimately formed a series of vast lakes. For English people the Devonian is mainly the age of the "Old Red Sandstone" rocks, which form so conspicuous a feature of the Devon coast. The dark red colour of these rocks is due to the deposit of iron round the grains of sand that compose them, and this points to a formation in inland lakes rather than the open sea. This change coincides with the first appearance of animals that live on land, and the connection of the two will be considered in a later chapter. The earth has been, not merely the passive theatre of the upward progress of life, but the great stimulus to its progress; and it is well to establish the evolution of the earth itself, on geological grounds, before we see the bearing of its changes on the procession of living things.

The Carboniferous period, which succeeded the Devonian, is probably the one best known to the general reader, and requires little description. After the

temporary depression of the Devonian period the land began to rise once more.   Large but low-lying tracts of land extended south from the original northern continents, and living things definitively settled on them. This settlement belongs to the two following chapters, and we need only recall here the extensive swamp forests that gradually covered so much of the earth.   In this case the development of life led to physical changes in the nature of the earth, which were to have a momentous reaction on living organisms in the succeeding ages. The vast forests began for the first time to reduce the stifling quantity of carbon dioxide in the atmosphere. There were as yet very few air-breathing animals, and the predominant feature was the absorption of carbon by the abundant vegetation.   Our vast stores of coal give us a sufficient idea of the quantity that was withdrawn from the atmosphere.   It was purified and prepared for a great increase of land-animals, and at the same time the rays of the sun were now enabled to penetrate and give a stimulating impulse to the development of life.

The inexpert reader will expect that the full penetration of the sun's rays to the surface of the earth would cause a rise in temperature, but the truth is exactly the reverse of this.   The carbon-saturated atmosphere had acted as a blanket for the earth's surface, and kept it hitherto at a high temperature from pole to pole.* Apart from some disputed traces of glacial action in the Cambrian period, geologists are agreed that to the end of the Carboniferous period the temperature was high and uniform, and the air very moist.   Then the clearing

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* Let us note in passing that the planetesimal theory rejects the idea of the atmosphere being filled with carbon dioxide from the start.   The indubitable abundance of carbon in the Carboniferous period is attributed to emission out of the crust of the earth in volcanic eruptions.

The Carboniferous Forest

of the atmosphere allowed a freer radiation of heat into space, and so led to a lowering of the temperature.

But further great changes were in progress at the end of the Carboniferous and during the Permian period which contributed to the fall of the earth's temperature. A great uplifting of the crust was taking place in various parts of the earth. Africa and South America now definitely appear on the geological map, and two further (and now lost) continents rise which connect Africa with Brazil on the one hand, and with India and Australia on the other. A chain of mountains (the Hereynian) surges upward from Brittany to Bohemia, and in America a more formidable chain (the Appalachian) rises and lifts the land adjoining it. The land-surface of the earth was now very considerable, the changes in the distribution of land and water had a profound effect on their living populations, and the climatic changes were not less stimulating. For the first time we find at least plausible traces of climatic zones and seasons, and in the higher lands we get the first confident traces of glacial action.

As far as present evidence goes in geology we have disputed traces of glaciation in the Cambrian period, certain traces in the Permian, and overwhelming proof that in comparatively recent times a vast ice-sheet covered the greater part of Europe and the northern part of America. What the cause was of this repeated appearance of colossal ice-caps outside of what are now the polar regions (though even they then had semi-tropical vegetation) geologists are by no means agreed. The most popular theory, so to say, is the familiar one of Dr. Croll, that the earth's axis slowly and periodically changes its position, so that the pole and polar cap is slowly and periodically displaced. The recent discovery of glaciation in the Permian period and the claim of discoveries of glacial action in other periods is thought

by those who follow this theory to lend it a striking confirmation. Such a claim is premature. In the long story of the earth there must have been, on Dr. Croll's principles, so many glacial periods that a very large number must be discovered to establish his theory. On the other hand, the geological record in the rocks is so rough and so little explored as yet that the theory is by no means discredited by the present scantiness of evidence. However, most modern geologists look elsewhere for the causes of periods of intense cold. Some speak of atmospheric disturbance following volcanic action on a large scale: others think a change in the ocean currents might suffice. But the general feeling converges upon two plausible agencies. One of these is a purification of the atmosphere, and the other is the rise of the land to a higher level.

Both these causes were conspicuously at work during or before the Permian period. It is calculated that our coal-forests (and rocks that absorbed carbon) must have taken from the Carboniferous atmosphere from 20,000 to 100,000 times the quantity of carbon dioxide that there is in the actual atmosphere. When we find this abnormal change succeeded by a great upheaval of land we seem to have an adequate explanation of the ice-sheets of which we find traces in the Permian strata. Some geologists do not hesitate to say that these changes represent a " revolution " in the face of the earth; though we must remember that they occupied probably four or five million years. They certainly involved consequences of the first importance for living things. The ice-clothed areas imply much larger tracts with a lowered temperature, and there is hardly any agency in nature so productive of biological changes as the lowering of temperature.

This revolution brings us to the close of the first or

Primary (or Paleozoic) stretch of the earth's history.
As far as the story of living things is concerned, it was
mainly a period of preparation of the land for the higher
phases of animal life, and therefore the broad changes
we have noticed must be clearly borne in mind.   The ex-
tension and solidification of the continents, the purifica-
tion of the atmosphere, and the lowering of the earth's
temperature and initiation of seasons and zones of
climate, were the chief changes that took place, from the
general evolutionary point of view.   But these changes
occupied an enormous period of time.   If we grant
50 million years for the entire formation of the stratified
crust of the earth, we must assign more than 30 millions
of this to the Primary epoch.   How long it may actually
have lasted it is difficult to say.   Professor Sollas, in
one of the most recent and careful estimates (in his *Age
of the Earth*) concludes that the formation of the crust
occupied probably between 50 and 60 million years.
Lord Avebury in a recent work (*The Scenery of England*)
suggests 100 million years.   Walcott thinks 27 millions
enough.   We may say, in a word, that the more weighty
estimates of geological time (for the stratified rocks)
range from 20 to 100 million years, and leave the point
—which is of little importance—for some future genera-
tion to determine.

It is not necessary for our purpose to study the
succeeding geological periods in detail, but one or two
broad changes must be noted.   In the secondary epoch
(which embraces the Triassic, Jurassic, and Cretaceous
strata) the climate slowly rises once more and the ice-
sheets melt away.   In Europe especially, the crust sinks
lower and lower, until Europe becomes little more than
a widely scattered group of islands (the peaks of its
mountains) peeping out of a semi-tropical sea.   In the
third part of the period the ocean that overlies the whole

of Southern Europe is filled with minute organisms which form skeletons or shells of the chalk or lime in it, and as they die their shells sink in countless myriads to the bottom—to form the vast beds of chalk that stretch from England to the south of Russia. As the period draws to an end the land rises once more, and the climate becomes colder. Another and greater period of the formation of mountains sets in. In America the Rocky Mountains and the Andes heave slowly upward from the level of the earth, and in Europe the Pyrenees and the earliest Alps appear.

The whole period occupied about 10 million years (taking 50 millions for the entire geological history), and, if we follow Professor Sollas, we may assume that the millions of tons of sediment deposited in the ample secondary oceans now had its inevitable reaction, and the great mountain chains were pushed upward. This involved a lowering of the climate, first in America, then in Europe. There is a general agreement amongst geologists that the climate was high and fairly uniform in the middle of the period (the Jurassic), when we find sub-tropical trees as far north as Greenland, and that it sank very considerably during the Cretaceous (or chalk) period. We shall see in the next chapter that deciduous trees—trees which shed their leaves as summer gives place to winter—make their first appearance at that time. There was, therefore, a great lowering of the temperature of the earth, and we shall see that this physical change had an effect of the utmost importance upon its living inhabitants.

The Tertiary epoch of the geologist (comprising the Eocene, Oligocene, Miocene, and Pliocene strata) brings the story down to within the last million years. Short as the period was, relatively to the preceding, it saw the most remarkable developments of plant and animal life,

and the gradual shaping of the face of the earth to something like its present configuration. Europe rose definitively from the waves (stretching out far beyond the present west coast of Ireland); Central America emerged, and linked the northern and southern continents; and the last fragments of the earlier continents that had united North America with Europe, and South America with Africa and Asia, sank beneath the ocean (or only lingered a little after the Tertiary epoch). The climate was on the whole genial, though the alternation of seasons now definitely set in. The penetration of a southern sea into the Mediterranean basin raised the temperature of the south of Europe. Palms flourished up to the north of France, and the lower portion of what is now Great Britain had a sub-tropical aspect. It is calculated that during the Oligocene and Miocene the average temperature of Southern Europe was from 10 to 12 degrees higher than it is to-day, while Greenland had a temperature 30 degrees higher than its actual one.

As the Tertiary epoch drew to a close the temperature fell once more, and again we find this phenomenon connected with a great rise of mountains. I have observed that it is well to keep a broad view of these climatic changes, and leave room for the action of various causes. Many writers point out that the great volcanic activity that had ensued on the formation of the Apennines and Pyrenees at the beginning of the Tertiary would pour volumes of carbon dioxide into the atmosphere, and so cause a rise of temperature. As the carbon was absorbed, the temperature would gradually sink once more. Others point out that the constant emergence and immergence of land would alter the ocean currents; and a reserve must still be made in regard to the astronomical theory. The tendency now is, however,

to turn rather to mountain formation, and it was in the last part of the Tertiary that the vast ranges of the Alps and the Himalayas were reared. The old phrase of the "everlasting hills" is sadly astray. The greater mountains are quite young in the general story of the earth: the greatest of them hardly more than two million years old.

Into the details of the last or actual geological period we cannot enter here. The deposits are so recent and superficial that it is impossible even to summarise the results of their study; nor is it necessary for our purpose. The outstanding phenomenon is the great ice-age that supervened. From six to eight million square miles of Europe and North America were buried under a sheet of ice that seems to have been 10,000 feet thick in Scandinavia and thinned gradually down to the valleys of the Thames and the Danube. From every mountain great glaciers spread over the country, and flowed together into a vast uneven ocean of ice. Nearly the whole of England (then part of the continent) down to the Thames is scarred and worn by the moving ice-sheet, and vast gravel-beds bear witness to the swollen rivers that bore away the waters as it melted.

The existence of this great mantle of ice over the upper part of the northern continents within recent geological times is now beyond question, but the questions as to the date and the causes of it are still under discussion; nor is it at all settled in particular places whether the scoring of the rocks was done by floating or by land-ice, nor how many times the ice-sheet crept down from the north and retreated, with temperate "interglacial" periods. Dr. Geikie claims six successive ice-sheets and five interglacial periods for Europe, and Professor Chamberlin gives the same for America; and some of the leading German geologists admit four or

five ice-sheets. As to the cause of this extraordinary
phenomenon we are still quite unsettled.   All the
theories I have mentioned in the course of this chapter
have their partizans—displacement of the earth's axis,
purification of the atmosphere, uplifting of the land,
change of the ocean currents, etc.—and the question
must be left open. It must be borne in mind that a fall
of a few degrees in temperature is said by many recent
students to be sufficient to account for the phenomenon.

As to the date and duration of the ice-age there is an
even greater difference of opinion.   Some geologists
bring the close of it down to 20,000 years ago, while
others make it begin nearly a million years ago.
Professor Keane says that (on Croll's principles) the
whole ice-age (with intervals) must have lasted from
700,000 to 800,000 years, and that it closed definitively
80,000 years ago.   Dr. A. R. Wallace (on the same
principles, somewhat modified) thinks it began 240,000
years ago, and lasted 160,000 years.   We can only say
that the most weighty of recent estimates put the climax
of the last ice-sheet (a relatively small one) at between
20,000 and 60,000 years ago, and the beginning of the
glacial period is hopelessly uncertain. This brings us
down to quite recent times, according to the geological
scale, and here we may leave the physical story of
the earth and turn to the development of its living
inhabitants.

CHAPTER IV

THE DEVELOPMENT OF THE PLANT

IN the course of the preceding chapter many a reader
will have felt that we were merely preparing the theatre,
as it were, for the drama of the evolution of life. In one
sense that is perfectly true, but we were really doing
very much more. A large amount of the interest of the
story of evolution is lost when the earth is regarded as
the passive stage of the transformations of living things.
Those physical changes in the earth's story which I
selected from the long geological record have had a
most profound effect upon organisms, and reveal half
the secret of their progress when they are attentively
considered. The strict specialisation of sciences in our
time—an essential condition of their advance—causes
many to overlook the vital connection between geological
changes and biological evolution, and it must be our task
to study them in close conjunction.

It is, therefore, in the light of the preceding story of
the earth that we will now follow the long procession of
organic forms that has passed over the surface of our
planet during the last fifty million years or more.
Further, in order to do so with any degree of instructive-
ness, we must make separate surveys of the evolution of
the plant and the animal. We shall find that there has
been a very close connection between them; but the
two great branches of the tree of life diverge so widely,
once they have parted from the primitive stock, that it
is somewhat confusing to attempt to follow both
together.

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When did the first living things first appear on this planet? Where did they come from? What was their character? These three questions naturally occur to one as of the greatest interest at the commencement of the story of organic evolution, and some attempt must be made at least to define the limits of our knowledge on the matter. Let us say at once that our knowledge is very limited indeed. We have not the smallest shred of direct information in regard to any one of these questions. For the later chapters in the story of organic evolution, we have a rich supply of documents in the fossilised remains of animals and plants that have been cut out of the rocks and stored in our museums. But a glance at any well-arranged collection of fossils shows at once the limitation of this information. It does not bring us anywhere near the real beginning of the story. The first fossil remains of plants are impressions of large and complex seaweeds in the Cambrian strata: the first animal remains are petrified Crustacea and traces of worms. These imply that the story of life had already run through whole volumes, during millions of years, and of these earlier volumes we have only charred masses of carbon, lime, and iron— the ashes, as it were, from the burning of those interesting early volumes. Of the very earliest we have no trace whatever.

The prevailing and proper attitude of the scientific man when confronted with our three questions is, therefore, one either of silence or of conjecture. He generally assumes, on good scientific ground, that the earliest living things appeared in the warm primitive ocean during what is called the Archæan period, because they are found to be already much advanced in organisation in the Cambrian strata. He further assumes that they were of an even simpler type than

the tiniest and lowliest specks of living matter that are found in nature to-day, because otherwise there could be no question of their evolution. And he further assumes that they were formed by natural development from some of the more complex chemical compounds in the primitive ocean. On this third assumption it will be advisable to dwell for a few pages.

A few years ago a Cambridge physicist, Mr. J. Butler Burke, was announced to have produced living things in the laboratory out of non-living matter. The sensation has died away, and his achievement is now usually dismissed with one of two contradictory charges. Some say that his "radiobes" are not living things at all: others say that he had not completely sterilised his material, and wandering germs had developed in it. It is clear that either one of these objections entirely destroys the other, and the truth lies between the two. In point of fact Mr. Burke never claimed to have produced living things,* and his results are very interesting. He allowed a small tube of radium-salts to send its emanation on some sterilised beef tea for a number of hours in a closed tube, and at length tiny specks appeared, which grew and sub-divided as microscopic organisms do. No bacteriologist could recognise them as living things, and as a matter of fact they died away after a few generations. They were not living things at all, but they showed that radium may quicken dead matter, and cause its particles to link themselves together into little structures that for a time assimilate matter and reproduce just as the lowest organisms do.

The importance of the experiment is that it suggests

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* See his *Origin of Life*. Mr. Burke was writing at the same time that I was publishing a little brochure (now out of print) on the subject, and neither knew of the other's title.

the presence of a life-giving agency in the primitive earth that has almost disappeared in our time. Physicists suspect that there are large quantities of radium in the sun to-day, and our earth would have a proportionate abundance in its incandescent stage. The question of the origin of life has long been obscured by Pasteur's supposed demonstration that there is no such thing as "spontaneous generation." All that Pasteur did was to show that the specific cases of "spontaneous generation" submitted to him were not genuine; and it must be added that Dr. Bastian has seriously challenged the value of his demonstration, and believes he has found cases of the rise of organisms (such as Bacteria) without living parents.* At all events the utmost Pasteur may be held to show is that living things are not formed *to-day* without living parents, or that no such case is known to us. There are, however, distinguished biologists, like Professor Naegeli, who hold the contrary; and even Professor J. A. Thomson thinks that protoplasm may be forming daily in nature in minute quantities.

The chief thing to remember is that, whatever happens to-day, the condition of the earth was radically different at the beginning of geological time. The matter of which it is composed had at one time a temperature that we cannot reproduce to-day, and radio-activity and electricity were intensely active. Here we have possibilities of combinations of matter and energy that greatly favour the view that life was first produced under natural conditions which have passed away for ever. Some physiologists, like Verworn and Preyer, believe that the essentially active and obscure principle of living matter is a radicle of cyanogen, a compound of

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* See his *Nature and Origin of Living Matter* (1905) and *Evolution of Life* (1907).

nitrogen and carbon. Now cyanogen is only produced at intense heat, and it is thought that great quantities of cyanic substances must have been formed when our earth was at a white heat. Hydrocarbons would be formed in the same way, and the primitive atmosphere and (later) ocean contained an abundance of salts. By the time that the ocean settled on the crust the ingredients of protoplasm would be present in plenty, and the natural energies then at work were peculiarly intense.

Further than this it is not yet possible to go. We can only give a vague indication of possibilities which it is quite hopeless to attempt to trace in detail. None of the many attempts to describe the origin of life in detail are at all satisfactory. The condition of the earth was so different at that time from even the most artificial conditions set up in the laboratory that the man of science usually declines to consider the problem. If ever science can raise a large quantity of mixed matter to a temperature of 7,000 degrees or so, let it cool gradually, subject it to a pressure of 250 atmospheres, quicken it with electrical energy and radio-activity at the due intensity, etc., it may have some chance of reconstructing the story of the origin of life. Until then it is content to say: If evolution accounts for the rise of the most complex chemical compounds out of a simple ether, and if it equally accounts for the advance of the highest animals out of the simplest microscopic organism, we assume that the comparatively short and obscure link between the two was also a matter of evolution.

It is now clear that we must equally dispense with definite answers to our other two questions. There was no " first " organism, and there was no point of time at which life could be said to make its appearance. From the fire-mist onward some of the material of the earth

was slowly developing in the direction of life. It must
have passed through myriads of phases, and it would be
just as difficult to pick out one of these as "the beginning
of life" as to fasten on a particular point in the dawn as
the time when the day begins and the night ceases. It
is utterly impossible for us to reproduce those successive
transformations which ended in the production of living
plasm. We must select our point arbitrarily, and the
best thing to do is to assume a time when minute
particles of this plasm are found to be living independent
and individual lives in the primitive ocean. The
geological record gives us no assistance. Not only
would these specks of jelly-like stuff not be preserved,
not only would the traces of them be burnt up or other-
wise destroyed in the intense heat and pressure of the
early rocks if they were preserved, but in point of
fact they did not (normally) die at all. The lowest
organisms may not improperly be described as immortal.
They may be poisoned, but usually each merely sub-
divides into two new creatures and nothing in the nature
of a corpse is left behind.

We have therefore to look for the lowliest of existing
organisms and gather from these some idea what primi-
tive types of life were like. Some writers take the
Amœba as one of the simplest known types of life, but
this is far from correct, as we shall see. We find still
lower types in the botanical world, and may take the
Nitrobacteria and the Chromacea as representing the
simplest form of life that is found in nature to-day.
Many groups of the Chromacea are familiar to every
reader in a rough way. The grayish or greenish deposit
that one so often sees on damp rocks or wood consists
of countless millions of them. If we put a little under
the microscope, at high power, we may single out
the tiny specks that represent each individual plant.

Here we have life in its simplest known expression. A minute globule of plasm, often less than a thousandth of an inch in diameter, lies like a mere speck of gum or jelly on the field of the microscope. It has no organs, in the ordinary sense of the word, no nucleus, and no membrane. Its "life" consists entirely in absorbing matter, by physical and chemical processes, from the surrounding moisture, increasing in size, and then breaking slowly into two daughter cells.

Some such type may be taken as the early forerunner of all the countless species of animals and plants that now people the earth. At some date after the ocean had sufficiently cooled to admit the presence of living things, swarms of these "microbes" made their appearance in it, as the outcome of that long evolution of protoplasm which it is so difficult for us to trace. Whether these early organisms were of an animal or a vegetal nature is not so easily settled as is often supposed. The distinction between plant and animal is by no means easy when we reach the simpler forms of life. In fact, not only is the whole group of the Bacteria claimed by both the zoologist and the botanist (though they are now generally left to the latter), but fairly advanced creatures like the Volvox are still much disputed. Movement is no test; the Diatom moves more freely and gracefully than the Amœba. Sensitiveness is not a rigid test, as many plants are more sensitive than the lowest animals. The usual test (though even this cannot be applied rigorously) is whether the organism lives on organic or inorganic food—whether it takes its protoplasm ready-made from other organisms, living or dead, or absorbs inorganic matter and converts this into protoplasm.

In this sense the first living things are generally regarded as being of a vegetal nature, though there are exceptions. Some writers, indeed, would put the whole

of these very lowly organisms in a special group, the Monera, below the level of the distinction between animal and plant. However that may be, the plant and animal must have diverged from a common stock at a very early date. If an organism can feed on inorganic matter it has little or no need to travel, and no stimulus to develop organs of sense-perception. On the other hand, the animal must move about in search of its rarer food (or else have long lashes to beat the water and bring the food to it), and an increasing degree of sensitiveness will be a great advantage to it in its travels. Thus we get the broad lines of the evolution of the plant and the animal. The one will become (generally) an inert and motionless structure, sucking food from the soil where it is cast, and at a later stage from the air about it, and growing a thick, tough skin, because it needs no sensitiveness to the waves of light and other stimuli. The other, the animal, will specialise on organs of locomotion and sensitiveness, and pass on through the fish stage to that of the higher land animal.

The evolution of the plant is not only of less general interest than that of the animal, but it is more obscure, and must be treated here very briefly. We need, in fact, do little more than describe the various kinds of plants that make their successive appearance in the geological record. In the Cambrian strata the botanist claims to find the first traces of early plant life. These fossils (Eophyton and Oldhamia) are by no means undisputed, but they are (if vegetal) of the same general character as those in the Silurian period, and may be taken to represent the lowest type of plant preserved in the rocks. From what we have seen above, it will be expected that they by no means belong to the lowest groups of living things. They are large plants of the seaweed type, and imply that innumerable generations

of plants had preceded them in the history of the earth.

What the line of development was up to these large marine Algæ we can only conjecture by arranging in a series the lower plants that we find in nature to-day. We have tiny plant-cells (like *Chroococeus*) living separate lives of the utmost simplicity : we have next cells of the same type living in a common jelly-like deposit (as in *Aphanocapsa*): in *Glœlocapsa* the cells come closer together: in *Volvox* they form definite and orderly structures, making a multicellular (many-celled) organism. This was undoubtedly the way in which the primitive single-celled organisms came to form composite (or multicellular) bodies ; but we will return to this point in the next chapter. A dip in almost any old rain-gutter will bring up specimens of each stage in the process.

The more interesting point is to see how these simple Thallophyta, as the botanist calls them, lead on to our familiar mosses, ferns, and flowering plants; and this is by no means easy. Let us first read the story as it is suggested by the geological record. By the Silurian period the waters of the ocean swarmed with Algæ, from the single microscopic cell to the large branching sea-weeds that grew up from the floor of the sea. The land was meantime rising above the surface of the water, and on some shallow shore or in some evaporating lake the plant adapted its structure to life on land. We shall see a more interesting adaptation of that kind when we come to deal with animal evolution. Before the end of the Silurian period we find traces of land vegetation, "and we can," says one of our leading geologists, " dimly picture the Silurian land with its waving thickets of fern, above which lycopod trees raised their fluted and scarred stems, threw out their scaly moss-like branches, and shed ther spiky cones."

The order of development, and especially the manner of
it, are by no means established.   It is usual to speak of
the Bryophyta (mosses and liverworts) as developed
from the Algæ, and leading on in turn to the ferns and
other Pteridophyta; but they may be divergent de-
scendants of a common Alga-ancestor.   In some as yet
unopened tomb in the geological strata we may in time
find the connecting links.   At present we have a rapid
and sudden appearance of one type of plant after another.
The marine Algæ continue in the Devonian period, and
the land is now overrun with giant ferns, club-mosses,
and horse-tails (to use the names of their small modern
representatives).   Coniferous trees of the pine and yew
order appear—apparently in the drier uplands—as the
period passes into the Carboniferous, or the age of the
great coal forests.   Then the low-lying swampy lands
that have emerged during the Devonian period take on a
mantle of the most luxuriant vegetation, and the plant
climbs to higher types on the rising ground beyond.

Those sombre and fantastic forests of the Coal-age
have been so often described and depicted that we need
not dwell on them.   The nearest picture we have on the
earth to-day is probably in the New Zealand forests of
araucarias and tree-ferns, but even these convey an im-
perfect idea.   No bird as yet enlivened the stillness with
its song or brightened the scene with its plumage; no
flower relieved the dull monotony of the vegetation; no
grass covered the soil; and little sunlight pierced through
the carbon-laden atmosphere.   Ferns of all sizes, some
sending up their fronds to a height of twenty feet,
formed the great bulk of the vegetation.   Lepidodendra
reared their huge stems, clothed in scale-like leaves and
ending in a massive club (giant club-mosses), to a height
of forty to sixty feet.   Sigillaria, the giants of the
forests, sent up their gaunt stems to a height of seventy
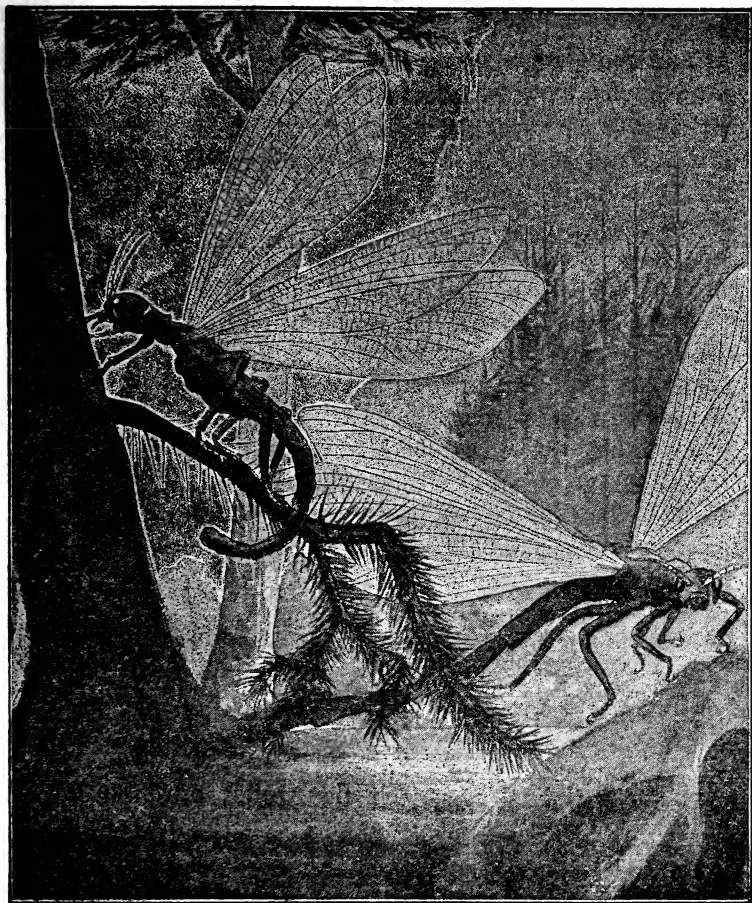
PRIMITIVE INSECTS IN THE COAL FOREST
(*Titanophasma Fayoli* and *Protophasma Dumasii*)

or a hundred feet. The more graceful and reed-like
Calamites (giant horse-tails) grew in thickets from the
surface of the abounding lagoons. The conifers were
creeping slowly down to the plains, as the land rose and
the flash of a glacier coming from some hill here and
there relieved the dank and stifling monotony of the
swamps, and drawing nearer to the modern type.

We will not linger over the much-debated question of
the relationship of these early conifers (or Gymnos-
perms) to the ferns and mosses (Crytogams)—the
modern botanist sees some trace of a transition in
the actual Ginkgo—but a word may be said on the
formation of the coal. The fossilised remains of the Car-
boniferous forests occur in seams that are often separated
from each other by layers of sand and mud. This led
earlier geologists to conceive that the land rose above
the water and sank again time after time, so that a
forest was buried under the sand and mud of the sea or
lake, and another forest grew above when the crust of
the earth arose again above the surface. Most modern
geologists are reluctant to admit this repeated oscillation
of the crust within one period. They are more disposed
to think that the coal-trees did not grow at the spots
where we find them to-day, but were washed down by
violent rivers from the higher ground into the lakes or
estuaries. Some, however, like Professor Chamberlin,
still hold the older view that our masses of carbonised
vegetation grew where we find them.

It will be remembered, from the last chapter, that
after the Carboniferous period the mountains began to
rise, and the dry, firm land to gain on the ocean. The
atmosphere, too, began to grow clearer and drier, and
the light of the sun to penetrate more freely. As these
physical movements go on we find in the geological
record a corresponding change in the plant population.

The great Lepidodendra and Sigillaria disappear, and the cycads and conifers gain the upper hand. The swamp area is being reduced, and the solid continental surfaces are growing. By the end of the Primary epoch the old forms have almost entirely disappeared, and we have an age of Gymnosperms (cycads and conifers) with the survivors of the great fern family. In the next, the Cretaceous period, the Angiosperms, or highest type of plants, make their appearance and supersede the older types. A large number of trees and flowering plants that are familiar to us to-day have left their leaves and branches in the Cretaceous strata. The brighter earth was beginning to bear the aspect which it would later present to the eyes of man. Not only palms, but the oak, maple, willow, beech, poplar, walnut, sycamore, laurel, myrtle, fig, plane, ivy, magnolia, and many others, spread quickly over the land from Greenland (then part of the northern continent) to the south of Europe.

In spite of local traces of glaciation, the climate of the earth was still generally warm. The abundant vegetation that has been found in the Cretaceous strata of North Greenland includes scores of different kinds of ferns, and the laurel, fig, and magnolia, and thus betrays a temperature 30°C above that it has to-day. But trees now appear (in the Cretaceous) that shed their leaves periodically, and we know that a winter season has set in, and the climate of the earth is growing colder. Palms still flourish in high latitudes, the flowering plants continue to advance toward present types, and grasses (of an early type) begin to clothe the plains. As the Tertiary epoch wears on, and the cold increases, Europe takes on a clothing of evergreens, and finally only patches of moss and arctic vegetation peep out of the snows for the reindeer to browse on; while the flowering plants develop their myriads of forms and hues

in the southern continents. At last the great ice-sheet descends over Europe and North America, and as it melts away the temperate plants creep up from the south and clothe our latitudes with its familiar vegetation.

This broad glance at the evolution of the plant world as a whole must suffice for the purpose of our brief story. The transformation of the leaves of the higher plant into sex organs and flowers would take us beyond our limits, and the many questions of the relationship of the different types are too controversial and technical to discuss here. The links may one day be found in strata that are not yet uncovered, and indeed botanists find a large number of transitional features in the early representatives of all the chief groups. We pass on to the more interesting study of the evolution of animal forms, which will bring us to the consideration of man's own development.

CHAPTER V

THE DEVELOPMENT OF THE ANIMAL WORLD

BEFORE we begin to trace the growth of the tree of animal life from the primitive " microbe " to the human being it is necessary to say a few words on certain controversies that divide scientific men in regard to biological evolution. Of the fact of the derivation of the higher species of animals from the lower, no zoologist in England has now the slightest doubt, or would spend five minutes in proving that general fact. There are, of course, disputes as to the relationship of particular groups of animals, but these will generally lie beyond the limits of this small work, and will be respected. But the general reader who only occasionally dips into evolutionary literature will have a confused feeling that there are still great and general controversies seething in the zoological world, and he may be grateful for an introductory page on the relations of Lamarck, Darwin, Weismann, and De Vries (representing Mendelism or Mutationism).

For Lamarck, who worked in the faint dawn of evolutionary science, the great agencies at work in development were adaptation and heredity. These agencies are thoroughly sound, but Lamarck applied them in a way which most of our zoologists are not now willing to accept. Let us take the development of wings in the bat. A small early mammal with somewhat webby fore-limbs has in this an advantage over its rivals. As the web or skin extends, it can use it as wings and fly. Now Lamarck (while not explaining how

the web first appeared) thought that the flying exertions of the early bat would strengthen and extend the web during its individual life (as a limb is improved by exercise), and that the improvement gained by the individual would be inherited by its progeny. If this went on for many generations the full evolution of the bat's patagium would be easy to understand.

Until recent decades this was held by all evolutionists, but Weismann and his school are wholly opposed to it. Weismann's theory of germ-plasm—a theory that only the germinal matter passes from parent to offspring—is quite inconsistent with it, and it is claimed that experiment decides against it. There is, according to this school, no inheritance whatever of characters or improvements acquired by the individual in his single life-time.* According to Weismann, the variation one finds in offspring of the same species or parents is due to different tendencies in the germ-plasm, or differences in the nutrition of parts of the germ, etc. There is a struggle for food going on between the particles that compose the germ, and as one or other prevails it will tend to develop or modify an organ in a special way in the adult body. So the variations arise by chance, so to say, or without purpose. If they are useful, the individuals are preserved, and the germ-plasm goes on developing them —say the webby fore-limb of the bat—in succeeding

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* This is now the prevailing opinion amongst zoologists. Francis Darwin and Sir W. Turner are among the few opponents of distinction in England. In Germany, however, a number of eminent zoologists (Eimer, Haeckel, Hering, Zehnder, Plate, Kassowitz, etc.) still maintain the Lamarckian position, and it has many supporters in France, America, and elsewhere. On the other hand, Weismann says that there are only two authorities in Europe (Professors J. A. Thomson and Emery) who admit his whole system, and this is hardly true of Professor Thomson.

generations. This is the gist of the controversy connected with the name of Weismann, but the elaborate details of his system must be read in his works.

Weismann is a thorough Darwinian. The characteristic point of Darwin's work was to show the action of the insufficiency of food, the consequent struggle for life, and the selection (or survival) of the fittest or best-equipped in the struggle. This Weismann fully accepts, and adds an explanation of the cause of variations which Darwin had not discussed. So far the essential principles of Darwin's work remain, and it is absurd to speak of them as abandoned.

From another quarter, however, an important detail of Darwin's theory has been called in question, and this is the last general issue we need raise here. Darwin clearly supposed that a new organ or a new species of animal was evolved very gradually. Only slight changes or improvements occurred in each generation, and it would normally take thousands of generations to evolve a new species. This seemed to be quite in accord with the course of nature, in view of the comparative fixity of species within historic times. But it has lately been discovered that new species may be formed quite rapidly and suddenly. An artificial interference with the coupling of the germs may give rise to an organism with such distinct characters as to constitute a new species. An Austrian abbot, Mendel, found this by experiments on plants years ago, and the distinguished Dutch botanist, Hugo de Vries, has extended them, and now has many supporters of his system of Mendelism or Mutationism—the theory that new species were largely sudden formations.

These are the bare outlines of the theories that must be borne in mind in considering evolution, and it will be only proper in this work to avoid positions

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that involve disputed points. Whether the bat got
its wings gradually on the lines of Lamarck's, Darwin's,
or Weismann's theory, or more rapidly, by large
changes, we shall not need to determine. But the
reader will avoid confusion by remembering that it is
only in this secondary sense that Darwinism is "dis-
puted" or "abandoned." Charles Darwin's son is one
of the most distinguished supporters of the mutation
theory. In point of fact it would be a great advantage
in the story of evolution to know that certain new
structures or features were somewhat suddenly de-
veloped. It is precisely the early (and almost useless)
stages of useful organs that chiefly puzzle the evolu-
tionist. If we may imagine that violent changes in the
earth's story—the flooding of districts owing to a sinking
of level, or the occurrence of an ice-age—threw species
into confusion and led to mixed breeding, and this led to
mutations, the work is easier. But I am constrained to
warn the reader that "mutations" have only been
observed in a few cases, and those mostly of the vegetal
world, so that it is precarious as yet to make a system
of them.

We may now return to our primitive ocean, and take
up once more the story of the evolution of life. Again
we must have recourse to careful speculation in studying
the earlier development of the animal world. Not until
the animal had developed hard or tough parts could its
remains be preserved in the mud or sand at the floor of
the sea, and it passed through numbers of forms before it
reached this stage. Moreover, the earliest remains that
were preserved have apparently been charred into mere
masses of graphite or ground into shapeless limestone.
When the first fossils appear, the story of development

has already run through several volumes, and a great variety of forms is found.

In view of this scantiness of direct evidence we will not linger long over the early stages of animal evolution. We have, however, two lines of indirect evidence with which we can reconstruct the story to some extent. The first means is to arrange the lowest of existing animals in the order of their degree of organisation, and see how far they will suggest the line of development. It often occurs to readers to see an objection to the principle of evolution in the fact that animals of the very simplest type are found in nature to-day much as we assume them to have been fifty million years ago. Bacteria were at work on the trees in the Carboniferous forests as they are at work in the forest to-day. Indeed, the Amœba that we find to-day in the pond or the rain-gutter seems to be an almost unchanged descendant of one of the earliest forms of animal life. But a simple explanation can soon be found. The lowest environment remains suited to the lowest forms of life. When the more gifted relatives of an animal pass on to a different environment or diet, the old environment remains for the unchanged. The struggle for life does not tend to *suppress* a species, but to keep down its numbers. The water is still an ample home for myriads of fishes when some of their number have advanced to the land. It would not be an advantage for *all* to turn into land animals.

Hence it is that we have still animals at every stage of organisation. The microscopic Amœba, gliding like a drop of sluggish oil along the slide of the microscope, merely pushing out broad and ever-changing projections of its substance as a vague suggestion of limbs, and wrapping itself round a particle of food—or even ar

indigestible particle—that lies in its path, is almost the
simplest form of definitely animal life that we can
conceive.* Then we have a simple type (the Monad)
with a single lash to use as an oar for locomotion. We
have animals (still microscopic) in which a number of
single cells with lashes (or cilia) are united in a
compound animal. Higher in the scale the cluster of
cells doubles in on itself (as a boy forces in one half of a
soft indiarubber ball upon the other), and the internal
layer of cells does the work of digestion, the outer layer
the work of locomotion, for the whole. Higher still,
some of the cells specialise as germ or sex cells, and
some as sensitive cells. Then the sensitive cells gather
at the head, the digestive cells only line the inner cavity
(or stomach), and the other groups of cells take up the
special tasks of locomotion, excretion, and so on.

We find strong reason to think that this was the main
line of the evolution of the animal body, when we turn
to the second piece of indirect evidence to which I
referred. It was known even before the time of Darwin
that all animals in their individual embryonic develop-
ment pass through a series of forms which more or less
reproduce the forms of their successive ancestors in past
time. The reproduction is not at all clear or complete
in the case of the higher animals, for the simple reason
that the embryonic life itself has in the meantime been
undergoing evolution ; besides that the series has to be
abridged for reasons of economy when it becomes very
long. But there is now a general agreement amongst

* I hinted that the Amœba is not so simple a matter as is
often imagined. Its plasm has a good deal of structure (though
no permanent organs) under a high power of the microscope
(one-twelfth and upwards), and it secretes a kind of acid
(" gastric juice ") to digest its food in its temporary stomach
(or vacuole).

the leading authorities that this remarkable reminiscence of earlier ancestors really occurs in an animal's embryonic development, and we shall see some very curious and beautiful illustrations of it as we proceed. For the earlier stages we have only to watch the embryonic development of some low type of animal—a coral, or a sponge, or even a worm—and we find the series of forms as I have just suggested it. Each animal is at first a tiny single cell, and in its immature stage this cell—the ovum or egg—is amœboid. It divides and sub-divides until it forms a round cluster with a hollow centre. The round hollow ball doubles in on itself (or "invaginates"), and—in free-swimming embryos at this stage—the outer layer of cells attends to locomotion, the inner layer to digestion.

On these lines we conjecture with some confidence what the early stages of animal evolution were. The single cell is capable of a vast amount of development while remaining a single cell, as the populous world of the Protozoa—one-celled, microscopic animals—shows. Some remain of the Amœba type, with a rough kind of temporary limb and no permanent mouth. Others develop permanent organs of locomotion, lashes (cilia or flagella), with which they beat the water like oars, and a permanent mouth and gullet. Others attach themselves to long fixed stalks—like the Vorticella—and have a crown of cilia round the mouth by which they make little whirlpools in the water and bring the food to them. Others shoot out their plasm in long star-like streamers —like the pretty Heliozoa—and catch their food in it; some develop these into a kind of dart or harpoon. Others grow a hard and often beautiful shell, and we get the Foraminifers and Radiolaria; while others take to parasitism, and may develop piercing and suctorial organs.

Leaving behind this very varied and interesting world of the one-celled animals, we have to see how the higher (many-celled) animal was evolved. The primitive microbes would tend to cluster together in groups, and live a communal life. Each cell must be in communication with the water to get its food, and the result would be a round cluster of microbes—let us now call them cells —with a hollow interior. In moving through the water, or resting at the bottom, one part of the cluster would be in a better position to take in food than the rest, and would specialise on digestion. The "digestive" part of the ball would tend to sink inwards, until the ball doubled on itself. The edges drew closer together, and at length we get an animal with an inner layer of digestive cells (a stomach), a mouth, and an outer layer of cells more or less sensitive, and armed with cilia for locomotion. We have plenty of examples of this in nature still.

At this point there were two alternatives for the developing animal. It might attach itself, for security, to the floor of the ocean, and develop arms for reaching out after its food, or an apparatus for making little whirlpools and bringing the food to it; or it might swim about in search of its food. The sponges, polyps, corals, hydræ, and anemones chose the sedentary life, and developed organs of the type suggested. As early as the Cambrian strata we find relics of the coral, sponge, and hydrozoan. The sponges seem to have had a different protozoan ancestor (a Choanoflagellate) from the other higher animals. The lowest specimen (Proterospongia) differs comparatively little from a group of Choanoflagellates—there is a good deal of social life even amongst the one-celled animals—and the other types are developed from this. "There is," says Professor Minchin, "no group which so strikingly illustrates the theory of

evolution." The corals are a higher development on the same lines. They are found in co-operative communities in the Silurian period. The hydrozoa and medusæ are another line of very great interest. All these—and the medusæ—are essentially simple animals with mouth-opening and primitive stomach, but they have now developed rudimentary nerve and muscle cells and definite sex cells, as well as tentacles and streamers and stinging organs. A good idea of the typical structure can be obtained by flattening a Hydra—found in most ponds—under a moderate power (say one-eighth) of the microscope. Each cell in its body stands out with wonderful distinctness, if it is carefully placed.

So far the line of evolution is fairly traceable, but we now come to a point where it is very obscure. From these sessile or fixed animals none of the higher types have been developed. We have to turn to the other alternative—the animals that swam about in the water in search of food. Broadly speaking, it is clear that this habit would lead in time to the formation of a worm-like and ultimately fish-like organism; but the development in detail is difficult to follow. Consider the evolution of the boat. At first a clumsy tree-trunk hollowed out by fire, it has come, from the need of greater speed, to have a long, evenly-balanced (or bilateral) body, with a definite head and tail (or stem and stern). Its eye (look-out) is at the front, its excreta trail behind, its heart and heavier organs (machinery, etc.) are safely encased in the centre. Undoubtedly the same principles controlled the evolution of the fish, through a worm-like stage.*

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* Note carefully that I do not say "worm." I am thinking of a "water-worm" with a straight body and cilia, not of our misleading "earth-worm." The word "worm" is in fact now almost abandoned in zoology. In its time it covered a multitude of sins—in classification.

The pre-Cambrian ocean was now swarming with life. Its floors were dotted with sponges and corals and hydrozoa dragging down unwary swimmers, and the free-swimming animals had increased sufficiently to initiate the struggle for life. In this struggle the animals that chanced to have more evenly-balanced bodies, with the sensitive cells located at the front, were best fitted to survive. Rough sense-organs were developed in the head. A pair of depressions in the skin lined with pigment cells (to arrest and so better feel the light) represent the first eyes: we find them still in some lowly animals. Another couple of sensitive pits were the first nose. A third depression in the skin with a sort of stone rolling on a sensitive bed gave the animal some sense of equilibrium and direction, and was destined to become the ear of the land animal. A couple of rough channels for carrying off waste matter formed the first kidney system. The digested fluid food began to make definite channels (" blood-vessels ") in its course through the body. The stomach began to protect its entrance with a stout gullet. All these structures are really found to-day in animals that linger at the lower levels of development.

On these general lines we conceive the further evolution of the animal body—the formation of a definite head and tail and long bilateral body, sweeping through the water, like a Roman galley, by means of the rows of cilia on its flanks. Thousands of different types of this animal would be developed, and would offer various starting-points for the evolution of the higher animals. But I must pass very briefly over the rise of the higher invertebrate classes, which is very obscure, and come to the easier story of the evolution of the fish, the reptile, the bird, and the mammal.

If you examine in a museum a case of the earliest

fossils, of the Cambrian period, you find that the animal world is already well developed. There are not only corals and sponges, but Echinoderms, Molluscs, Worms and Crustacea in an advanced stage. Shell-fish abounded in the Cambrian sea, crinoids (sea-lilies) grew on their long stalks, and trilobites (highly developed Crustacea with compound eyes) and marine worms ploughed through the mud at the bottom. It is quite hopeless to attempt to trace the earlier evolution of these. There is a great gap in the geological record, and such earlier strata as we have, have been so charred by heat from below and crushed by pressure and ground by folding that they can tell us nothing. The land, it will be remembered, was now emerging very considerably above the water, and the struggle for life in the over-populated shallows must have been terrific. Passage to the land was the natural escape for those best fitted to effect it, and for ages selection would be at work developing the land animal; though it is well known that in periods of change and crisis evolution proceeds much more rapidly. As the soft, swimming animals came to touch the bottom (and for protection generally) they would find hard parts, external and internal skeletons, a great advantage. So the Molluscs get their shells, the Crustacea their coats of armour, the Worms their ringed structure, and the Echinoderms their hard coats; but we must frankly refrain from attempting to trace this evolution in detail.

Why do we speak so confidently of their evolution at all, when the crinoid and the trilobite and the mollusc come fully formed, as it were, on to the stage? We have a very good and simple reason, besides the general considerations we have seen above. From the moment these animals *do* come on the stage to recent times (or until they pass from it) they are in a continuous state of evolution. The shell-fish world affords us some of the

most beautiful illustrations of the theory of evolution; but I must send the reader to the pages of Professor Le Contes' *Elements of Geology* (last edition, revised by Professor Fairchild) for the lengthy story of the cuttle-fish, etc. The Echinoderms appear in successively higher forms, and the evolution of the different orders has been well traced by Professor MacBride (in the *Cambridge Natural History*). Probably all come from a primitive stalked form. The rays of the star-fish retain the flower-like spread of the arms, and in the sea-urchin these rays are curled up into a ball. More difficult is the evolution of the "worms" (now split into a bewildering classification), while the infinite variety of the Arthropods must be respectfully set aside in so short a sketch as this. Under this great group are comprised the aquatic Crustacea (water-flea, cyclops, lobster, crab, etc.), and the air-breathing Tracheates (centipedes, spiders, and the innumerable insects).

To attempt to sketch even superficially the way in which this vast and varied kingdom spread over the shores, the land, and the fresh waters of the rising continents, would be a lengthy and very difficult and precarious task. Curiously enough—it is a fine illustration of the law that the individual must pass to some extent through the forms of his ancestors—the members of this group that now seem farthest removed from the denizens of the sea still retain a most striking proof of their origin. I refer to the metamorphosis of the insect. The graceful dragon-fly seems hopelessly removed from the worm-like creatures of the pre-Cambrian ocean until you catch him in his early stages in the pond. Indeed, the order in which the insects make their appearance in the geological record is encouraging enough to the evolutionist. The first trace we have of them is a stray wing in the middle of the Silurian (more

properly in the Ordovician) strata.   In the Devonian we
have fairly abundant traces of insects.   They are unlike
any modern type, and have the general characters that
we look for in the ancestors of divergent families.   In
the luxuriant vegetation of the Carboniferous we
naturally find large numbers of fresh species.   They are
mostly of the Orthoptera (cockroaches, locusts, etc.) or
Neuroptera (may-flies) types, and we find no specimens
as yet of the Hymenoptera (ants, bees, etc.), Lepidoptera
(butterflies), or Diptera (house-fly, gnat, etc.).   In the
Triassic period the Coleoptera appear, and in the
Jurassic we find the first Hymenoptera—the highest
order.   By the beginning of the Tertiary all orders are
definitely and abundantly represented.   Even now,
however, the ants—of which there are more than a
hundred species—do not seem to have evolved a social
life. All are winged, so that the remarkable organisation
into male, female, and neuter, cannot yet have set in.

These geological indications, taken together with the
metamorphosis of the insect, give us ample guarantee of
the evolution of the insect world.   We must, however,
retrace our steps a little, and return to the pre-Cambrian
ocean with all its ancestral types, in order to take up
the thread of the evolution of the vertebrates, which will
soon lead us to firmer ground.   Once a bony framework
is set up in the animal, fossilisation becomes easy, and
our task is proportionately easier.

That the fish was developed from some one of those
early worm-like creatures in the pre-Cambrian ocean is
the almost universal opinion of geologists and zoologists.
A few, it is true, are inclined to look to the Ostracoderms
for the vertebrate ancestor.   In earlier geological works
the reader will find illustrations of what are called
"upper Silurian fishes" (*Cephalaspis*, *Pteraspis*, etc.)—
heavily-armoured creatures of a fish-like character.

These are the Ostracoderms, and are regarded by some as a connecting link between the Crustacea (trilobites) and the fishes. As they have no trace of the cartilaginous rod that represents the early back bone, most authorities deny them this position, and class them as an offshoot of the early Crustacea. The real fish ancestor seems to be found in *Palæospondylus*, a small back-boned animal, without ribs or limbs, found in the Scotch sandstone a few years ago. Many animals living to-day at the base of the fish world illustrate for us the growth of the back bone. In the young sea-squirt we find a thin rod of cartilage that is lost in the adult form; in the acorn-headed worm we have slight traces of such a rod; in the lancelet there is a complete rod from end to end; and in the lamprey this cartilaginous rod has closed over the spinal cord along the back and spread, as skull, over the brain at the head of it.

With this appearance of a stiffening rod, which will later turn into bone and break into articulating disks, we get the first vertebrate animal, or an early type of fish. The cilia are replaced as organs of locomotion by fins— folds of skin that are worked off in the motion through the water, and then converted into strong paddles by rods of cartilage. The sensitive pits in the skin have slowly developed into eyes and nostrils, and have their telegraphic nerves to the brain. The heart, beginning as a mere pressure bulb in the lower types, develops into a two-chambered pump, and sends a richer supply of blood to the frame. The water that enters the mouth now makes its exit by slits in the gullet and skin, and a fine network of blood-vessels grows over the slits to extract the oxygen from the water (respiration) as it issues. From the evidence of embryology and the illustrations we have in nature to-day we gather that this was the line of evolution of the fish.

Once more, if there is some obscurity about the first development of the fish, there is ample evidence of the action of evolution on the whole of its subsequent career. The earliest fishes we find, in the early Devonian, are of the simplest type—the shark and ray type (Elasmobranchs)—though some of the sharks soon attain the most formidable proportions, and have their jaws lined with saw-like triangular teeth five or six inches long. From these Elasmobranchs two great groups are developed in the Devonian waters, the Ganoids or scaly fishes and the Dipnoi or double breathers (having both gills and lungs). We are now at a great crisis in the development of animal life. Had the vertebrates remained in the water, their intelligence would not have advanced beyond that of the salmon. But with the multiplication of gigantic fishes, and the enormous development of teeth and armour (bony plates), the struggle in the waters became intense, and at the same time the land, as we saw, began to rise from the deep. Large tracts of the sea were caught in the rising continents and converted into the inland Devonian lakes, where the red sandstone was laid down. The struggle became fiercer in these shrinking lakes, and adaptation to land life became a most valuable advantage. It was then that the first fishes developed lungs for breathing the air, and started that new colony of land dwellers that was to culminate in man. Of the fishes that remained in the water we must compress a long story in a sentence, by saying that our sharks and dog-fish still represent the early cartilaginous type; but the Ganoids gave way before the later bony fishes (Teleosts), which appeared in the Jurassic, and branched out into the numerous types with which we are familiar. The Dipnoi claim closer attention.

In three different parts of the world—Australia, South

America, and Egypt—there are to-day "mud-fishes," with both lungs and gills, which breathe air during the dry season.   In India there is a perch (*Anabas scandens*) that can live for days out of water—though it has no lungs—and walk across rough country on its fins, or even climb trees; and on the shore of the Indian Ocean are other fishes (*Periophthalmus*) that remain on the shore quite happily in search of food when the tide recedes. These are admirable living illustrations of "the fish out of water," and enable us to understand the Devonian transition quite easily.   The Devonian mud-fish, of which we have fine fossil specimens, was in all essentials similar to the modern Australian mud-fish.   Probably its lungs are merely an adaptation of a pair of floating bladders to a new purpose.   The fish rises and falls in the water by compressing or expanding a bladder of air in its interior.   In some fishes the gas-bag is double, and in others it is well supplied with blood-vessels, or opens into the gullet.   Here were the bags for air-breathing provided in a rudimentary way, and selection soon developed the most efficient.

From this kind of fish to the amphibia is an easy transition, and we are not surprised to find salamander-like creatures in the Carboniferous rocks.   The two pairs of fins have now turned into short and clumsy limbs—a natural result of an animal walking on them— which terminate in broad webby feet with five toes. "Some of them have so plainly the characters of their fish ancestors with the beginning of the characters of their reptile descendants that they form," Le Conte says, "the most complete connecting link ever discovered." Indeed, we have so remarkable a chain of forms connect-ing the bird and the mammal with the fish—through the reptiles and amphibia—that it affords ample compensa- tion for the earlier obscurity of the ancestor of the fish.

Moreover, we shall see in the next chapter that there is, in their embryonic development, a most indisputable indication that all the existing birds and mammals had a remote fish ancestor. For the moment we must briefly trace the line of development of the vertebrate land animals.

From the Carboniferous swamps, with moderate-sized amphibia waddling through the mud, we pass on to the brighter Triassic landscapes. Much larger amphibia

GIANT REPTILE OF THE JURASSIC PERIOD
(Ceratosaurus)

now wander at the edge of the waters—the Mastodon-saurus with its great flat head measuring three feet by two, and the Labyrinthodon with teeth measuring three and a half by one and a half inches at the base. But a new type of animal—the reptile—has appeared, and we have plenty of evidence that it is evolved from the amphibian. There is the Rhyncosaurus, with great

parrot-like beak; the Plesiosaurus, with its long lizard-like body, the Deinosaurus, and many another formidable reptile. The climate is still warm, food abounds, and the reptile lords it over creation and grows to a prodigious size. As time goes on we get the voracious Ichthyosaurus, more than twenty feet long, with (sometimes) two hundred teeth, and eyes fifteen inches across: the Iguanodon, thirty feet long; the Megalosaurus, thirty feet long; the Ceteosaurus, fifty feet long; the Atlantosaurus, one hundred feet long; and the Brontosaurus, sixty-seven feet long and weighing probably ninety tons, which has left " on the sands of time "—or the Jurassic mud-flats—footprints that cover about a square yard. And overhead are grotesque flying lizards that have taken refuge in the air in the increasingly bloody struggle for life.

How all these giants came to perish, and the reptile world fell from its high estate to become a collection of skulking serpents and lizards and crocodiles would take us too far afield to consider. One word will suffice. Imagine the climate of the earth sinking considerably, so that the cold-blooded egg-laying reptile must move to the restricted regions where it is still warm enough for his life. Food will grow scarce, the little reptiles that need least food will survive, and the colossal creatures die out. If on top of this we assume the advent of a race of higher intelligence and greater speed, the explanation will be complete enough. And this is precisely what happened in the Cretaceous period.

The emergence of the continents in the Devonian, and the lowering of the temperature in the Cretaceous, stand out as critical points in the story of the earth. Towards the end of the Jurassic began that lowering of the temperature which culminated in the local glaciers and the deciduous trees of the Cretaceous. The change

in temperature and rainfall would not only reduce the rich swamp vegetation on which the large herbivorous monsters lived, but would of itself drive them either to retreat into hot and moist regions or to adapt themselves to the new conditions—to advance a step in organisation. Most of the reptiles perished, a few orders retreated to the south, and—what is most interesting— two distinct types adapted themselves (or evolved adaptation) to the new conditions, and became the ancestors of the bird and the mammal. To do this they needed to develop their scales into either feathers or fur, to improve the heart so as to become warm-blooded animals, and to evolve structures for developing their young inside the mother's body or by hatching.

The evolution of the bird from the reptile is plain, as several of the " missing links " have been discovered. In some German Jurassic limestone complete skeletons, with feathers, have been found of a creature (*Archæopteryx*) that combines features of the reptile and the bird. Its jaws are lined with teeth, it has claws on its wing limb as well as foot, and its long tail is that of a lizard with feathers growing out of each vertebra. Even later, fossil toothed birds (*Hesperornis*, etc.) have been found in the Cretaceous. With these links it is inevitable to connect the bird with the reptile. Some of the smaller Dinosaurs had hollow bones, and only four toes, and may be of a common ancestor with the bird. Probably they originated from one of the smaller leaping lizards with broader scales on its feet. An expansion of the scales would tend to give a fan-like action on the air and lengthen the leap, and in time the fore-limb would evolve into a wing. The claws would then cease to be of use and die away.

To follow the development of the Archæopteryx into the wide-branching family of the modern birds would be

THE EARLIEST BIRD
(*Archæopteryx*)

a colossal task which we must wholly avoid here. We turn rather to the second type of reptile that adapted itself to the changed conditions, and study the more interesting evolution of the mammals.

Australia cannot be said to be a conservative country since Dutch and Englishmen peopled it, but from the zoological point of view it is a conservative paradise. There we find the most primitive fishes, the most primitive lizards, and the most primitive of mammals and of natives. The duck-mole of Australia is what Darwin called "a living fossil." It connects the mammal and the reptile in a remarkable way. The punctures in its breast, through which the fat oozes, to be licked off by the young, just entitle it to the name of mammal ("mamma" means breast), but it lays eggs like the reptile, has a common outlet for its excreta, and other reptilian features. It is not only—with a few similar forms—the lowest type of existing mammal, but it illustrates remarkably the evolution of the mammal from the reptile. The earliest mammal skeletons we have are described as those of small insect-eating Monotremes ("with one outlet," like the duck-mole and spiny ant-eater). Recent geologists are inclined to think the evolution took place on the now sunken continent between Brazil and Africa, and there are, as a matter of fact, reptile skeletons found in South Africa which many identify as the ancestors of the mammal.

It is in the Jurassic strata that we first find these fateful little creatures that were destined to replace the colossal reptiles as lords of the earth. Their coat of hair fitted them to oppose the cold, their meagre insect diet enabled them to be independent of the decay of the luxuriant vegetation, and their four-chambered hearts supplied a richer and warmer blood to their frames. Partly from this richer supply of blood in a small frame,

partly from the anxieties of their frail existence, an organ was developed in them that the huge reptiles had not needed to cultivate. This was the brain. The ninety-ton Brontosaur appears to have had the brain of a nine-pound human infant, and all his cousins had the slenderest amount of brain in their formidable skulls. The race now began to depend more on intelligence; possibly the new development of maternal feeling, in the greater care of the young, increased the accent on mind.

At all events the new inhabitant of the planet spread rapidly over its surface. Before the end of the Jurassic we find thirty-three genera of mammals, ranging from Europe to America across the "lost Atlantis." All belonged to the lowest classes of the mammal world, the Monotremes and Marsupials, in which the uterine arrangements are of a primitive order. Some authorities think that the whole of them were Marsupials—leaping animals of the opossum type, bearing their young in pouches or folds of the skin. Whether these Marsupials were developed from the Monotreme, as some think, or both had a common reptile ancestor, we may leave open. However that may be, we know that these Marsupials gradually overran the earth, penetrating to South America on the one hand, and Australia on the other. Australia seems to have been cut off from about the end of the Secondary epoch, and this accounts for the fact of its mammals remaining at the marsupial stage.

From one or other of these early mammals all the varied forms we are familiar with have been evolved. Once more we must refrain from an attempt to trace the lines of their descent, on account of the magnitude and conjectural nature of the task. The fossil remains we have from the beginning of the Tertiary epoch are in complete accord with the theory of evolution. At first

we have very vague and generalised forms, with sufficient traces of their marsupial ancestry, yet pointing clearly enough to the future horse, fox, pig, etc. The great improvement of the plant world during and after the Cretaceous (see last chapter), and especially the evolution of grasses, leads to a wide extension and variety of the vegetarian mammals, and this in turn favours the carnivores. The struggle intensifies, with the usual effect of differentiation. In some the quality of speed is selected. The foot modifies into a hoof, and the horse, deer, etc., slowly appear in the successive strata. As is now well known, we can trace the horse back, and watch the disappearance of the missing toes, as far as the four-toed Orohippus of the Eocene period. With more or less success the lines of the other mammals are traced back to the same period. Early types of deer and antelopes (without horns), squirrels, hedgehogs, bats, and lemurs, are found in the Eocene. Some animals (Tillodonts) unite the characters of ungulates, rodents, and carnivores: others (Deinocerata), with heavy-horned skulls, remind us at once of the elephant and the rhinoceros. The lower temperature of the earth has now paralysed the reptiles, and opened a broad field for the warm-blooded animals.

With the Miocene we get a clearer development of the cat, bear, elephant (mastodon), rhinoceros, hippopotamus, lion, dolphin, beaver, otter, and other mammals. Still all are in ancestral stages, and far removed from the animals to which we now give those names. The Pliocene strata carry the story of their evolution a step further, and the gazelle, antelope, deer, giraffe, horse, ox, wild cat, bear, hyena, wolf, fox, glutton, seal, pig, musk-sheep, mole, elephant, etc., stand out with great distinctness on the closing scenes of the Tertiary epoch. There are still the million years or so of the Quaternary epoch

to run before human science will come to classify and explain—an ample period for the completion of mammal evolution—but we must now bring this over-lengthy chapter to a close, and be content to follow in greater detail the evolution of that important stem of the mammals which culminates in man.

CHAPTER VI

THE EVOLUTION OF MAN

AT the beginning of the last chapter I showed how the embryonic development of an animal throws light on its evolutionary ancestry. By some law, which I prefer to regard as still quite unexplained, the individual body must pass roughly through the series of forms which represent the long series of its ancestors in past time. The human body is subject to this law like all other animal frames, and we will first see what we can gather from its embryonic development in regard to the evolution of the species.

The ovum or germ of the human body is, in its mature form, a single cell or globule of plasm about one one-hundred-and-twentieth of an inch in diameter. It is surrounded by an elaborate membrane that quite cuts it off from the one-celled Protozoa; but if we go further back to its immature form—say in the ovary of a baby —we find it a more or less irregular and amœboid particle about one two-hundred-and-fortieth of an inch in diameter. In some of the lower classes of animals the ovum actually creeps about like the Amœba. Man begins his existence as a " microbe " therefore, and it is more wonderful that his complex frame should be built up from this in the space of nine months than that such an evolution should have been brought about in the space of fifty million years. After fertilisation the single cell grows into a cluster, and passes through the stages I described above. But, for the reasons I gave, these early stages are much complicated and modified in

the higher embryo, and we will pass to more obvious indications.

In the third week of development, when the embryo (less than a quarter of an inch long) has something of the appearance of a tadpole (minus the gills)—a large head and long tail, with no trace of limbs—a series of five slits or folds appears in the throat or chest region. That these (though not open) are real gill slits is seen at once on dissecting the embryo. The rudimentary heart is found to be in the position and of the same structure as that of the fish, and its chief arteries rise in six double arches over the gill arches. The whole of this distinctively "fish" arrangement—which is found also in the embryos of all other mammals, reptiles, and birds—has no function and no utility. It will entirely disappear within a week or two. It is a most striking illustration of the mysterious law of the reproduction of ancestral stages, and a most curious reminiscence of the Silurian fish ancestor of all the vertebrates. Nor is it the only clear indication of our fish ancestry. The nose makes its appearance—in the fourth week—as a pair of simple depressions in the skin, just as we find the organ of smell appearing in worm-like animals below the fish stage. The pits then connect with the mouth by an open groove (as in the shark): the grooves are closed over and become nostrils leading into the front of the mouth (as in the Dipnoi): and the successive development passes through the reptile and early mammal stage. The external prominence does not form until about the tenth week. The jaws, ears, limbs, heart, diaphragm, etc., show an equally interesting development. Before birth the whole body is covered with a coat of fine hair (like that of the ape); after birth the fingers and toes show a remarkable power of grasping (like those of the ape), and the spine is curved for a long period, so that

the baby must—not from mere weakness of legs—crawl on all fours.

There is another remarkable group of indications that tells us much about the evolution of man without any recourse to the geologist. Fine as the human frame undoubtedly is, from one point of view it may well be regarded as an "old curiosity shop" or museum of useless antiquities. It contains a number of organs and tissues that have no function, yet absorb the precious nourishment and are sometimes sources of mischief and danger. These are the so-called "rudimentary"—a bad word—or "vestigial" organs.

Some of these may easily be brought home to the inexpert. The fine coat of hair over the body is an obvious instance. It cannot be understood except as the degenerate relic of our ape-like ancestor's natural "fur coat." Indeed, we shall see that it was still well developed in prehistoric man less than 50,000 years ago. An interesting special point in it is the fact that the hair on the arm generally—not always—tends upward from wrist to elbow and downward from shoulder to elbow. We can only understand this as a reminiscence of the days when our thick-haired ancestor, perched in his primitive tree, made a thatched roof of his arms during the rain, as apes do. Changes of habit and taste have developed the hair luxuriously on the head and on the male's chin—an instance of sexual selection, or preference of females for bearded mates and males for smooth-faced ladies—and led to its general degradation.

The breasts of the human male provide another instance. That these are genuine milk glands is shown by the many known cases in which the male has suckled the young. Haeckel examined a young man in Ceylon who did this, and one of our English generals informs me that he has seen an old man suckling an infant on the roadside

in Madras. These male breasts clearly point back to a time when, in some ancestral stage, there was a more equitable division—from the mother's point of view—of the family work.* Moreover, we often find more than one pair of breasts (up to five pairs) in women, and sometimes in men. Here again (as Dr. A. R. Wallace has shown) we have an ancestral reminiscence. They are an arrest of mammary development at the stage of an ancestor with five, four, three, or two pairs of breasts.

Another easily verified instance is the external ear. This is often regarded as a kind of speaking trumpet, bringing the waves of sound to the internal ear. Now, the erect mobile ear of the cat or the horse is such a trumpet, but a trumpet flattened down with a hammer (and so useless) would be the correct equivalent of ours. Men whose ears have been cut off (in Bulgarian atrocities) do not suffer in hearing. And when the anatomist removes the skin round the ear he discovers a group of muscles attached to each human ear that are just as useless. Two of them (for pulling it backward or forward) can be used by many people, and one of the others can be used by a few; but they are quite useless, and two of them are never known to act. The whole apparatus only serves to remind us of our ape-like and earlier ancestors with erect ears, which they could pull in all directions to catch the waves of sound.

In the eye we have another vestigial structure. The little fleshy pad that we find at the inner corner of each eye, over the tear gland, has no function whatever. The only explanation of its existence there is that it is the

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* Haeckel attributes them rather to a transfer, by some freak of heredity, to the male; but the above is the general interpretation.

shrunken relic of a third eyelid possessed by our fish or reptile ancestor long ago. Observe the eagle or the turtle closely in the zoological garden. You notice that it occasionally flashes a third eyelid, or membrane, across the ball from the inner corner. This feature of the fish, bird, and reptile, has survived in the useless fleshy particle at the inner corner of the eyes of the mammals. Our fish or reptile ancestor had not only a third eyelid, but a third eye, in the top of its head. In nature to-day we find only a creature (Pyrosome) just below the vertebrate level with such an eye actually functioning. But through the reptile world we find this third eye more or less depraved; the skin has closed over it, but the hole or orbit remains in the top of the skull. Higher still in the animal scale the skull also closes over it, and then the brain. It survives in our brain to-day in the "pineal body"—a useless cone-shaped structure in the centre of the brain.

Metchnikoff enumerates more than a hundred structures in the human body that he calls "vestigial." Some of them—such as the thyroid and thymus glands and some uterine structures—seem to have taken on new functions, but there are many muscles and blood-vessels that have ceased to have a place—or a useful place—in the work of the body. Patches of muscle in various parts of the body—like that with which we "knit our brows"—are traces of the large and comprehensive muscle with which some remote ancestor twitched his skin to keep the flies off, as the horse does. The stumpy end of the back bone—similar to that of the anthropoid ape—is the last trace of a long-tailed ancestor. The human embryo has a long tail for a considerable period of its development, and cases occur in which children are born with real tails, which they wag in anger or pleasure, and which occasionally persist

for years in growing.   Many a hospital records cases of
human tail-cutting.   Finally, there is the well-known
"vermiform appendage," a little closed tube leading off
the bowel where the small intestine passes into the large.
Everybody knows how hard substances may force their
way into this tube, and set up the dangerous inflamma-
tion called "appendicitis."   The appendix is an un-
pleasant reminiscence of an early ancestor that we could

GIANT SALAMANDER OF THE COAL FOREST
(*Archegosaurus*)

well dispense with.   In some early vegetarian ancestor
this was a useful addition to the alimentary canal, giving
extra storage room for the coarse and slowly digested
diet.   With improvement in diet it has become super-
fluous, and has shrunken into this worm-like appendage.
    These two lines of evidence will quite prepare the
reader for considering the evolution of man, but we will
add a third.   The blood consists of a watery fluid in

which the familiar corpuscles float. It was found a few years ago that when the blood of different animals was mixed, the serum of one specimen sometimes destroyed the corpuscles in the other, leaving a deposit. Sometimes there was no action of one on the other, and it varied considerably in the case of different animals. After tens of thousands of experiments a clear law was established. The action of one specimen of blood on the other depended on, and varied with, the relationship of the animals whose blood was transfused. The test was applied to man and the anthropoid apes, and the result was in complete accord with the theory of a close relationship between them.

It is probably no longer necessary to warn even the general reader that man must not be regarded as evolved from any existing genus of ape. Neither the anthropoid ape nor the common monkey is in the line of man's ancestry, any more than the Germans are in the line of descent of the Anglo-Saxons. Man and the apes have come from a common ancestor, just as English and Germans have. The anthropoid apes are nearer, and the ordinary apes more remote, cousins of ours. But on the other hand it is necessary to remind many people that, in developing from this common ancestor to the human stage, our predecessors *must* have passed through an ape stage. This is so true that, as we shall see, when the earliest human remains were discovered fourteen years ago, authorities were pretty evenly divided in calling it an "ape" and a "man." They have only come to terms by calling it an "ape-man."

Let us now see if science can throw any light on this common ancestor, and on the way in which humanity was developed. The starting-point must be sought somewhere about the beginning, or possibly just before, the Tertiary epoch—at least two or three million years

ago. We saw that that was an age of increasing cold, of great physical changes, and of rapid biological evolution. The bony fishes had now appeared in the rivers, trees of a modern type and grasses covered the hills and plains, birds of many kinds—owls, eagles, swallows, parrots, etc.—filled the air, and the insect world had representatives of all its orders. The new lord of creation was the mammal—the kangaroo-like creatures that spread from Australia to America. The inevitable consequence of struggle amongst these— differentiation—set in during the Cretaceous period, and amongst the new types that appear in the Eocene are ape-like creatures similar to the modern lemur. To this group most zoologists look for the ancestor of the Primates, though one or two go a step further back. At all events the Eocene lemur (notably the *Adapis*, of which skeletons are found in France) must have been a very close relative of our Eocene ancestor, and may represent it for us. Amongst the large modern group of the Lemurs—scattered from Madagascar to Malaysia— the black lemur is nearest to the early type (in structure), but all of them will have evolved somewhat since Eocene days.

From the nature of the case we cannot identify any fossil remains as belonging to our line until they bear an actual human imprint, and this does not happen until near the close of the Tertiary epoch. It is, however, exceedingly improbable—to say the least—that any of the ape-like remains we have belong to our line. In the Miocene (mid-Tertiary) we find the first anthropoid ape (*Dryopithecus*), besides some that approach the anthropoid, and a number of ordinary apes. Then we have the "ape-man of Java" (*Pithecanthropus*), which some authorities refer to the Miocene, some to the Pliocene, and others leave uncertain.

⎯The direct or fossil evidence is therefore scanty, and justifies the ordinary text-book of science in almost entirely ignoring the question.   There is, however, hardly a zoologist in the world to-day who questions the evolution of man from an early lemur-like ancestor, and we may attempt to piece together their speculations in order to get some idea of that evolution.   It is clear that the lemurs had a wide distribution in the Old World early in the Tertiary epoch.   They have sufficient traces of their marsupial origin to explain whence they came, and the scattered localities in which their remains occur tell us something of what happened.   Africa (or the Afro-Asian continent that still existed in part) was apparently their first home.   They wandered northward over Europe, and westward across the remainder of the Brazil-African continent to America (or over the northern continent).   The Brazil-African continent disappeared early in the Tertiary, and the apes—the successors of the lemurs—developed separately in the Old and New Worlds into the Catarrhine (narrow-nosed) and Platyrrhine (broad-nosed) apes respectively.   The lemurs themselves, small and timid creatures, were extinguished in Europe and America.   They are found to-day only in Madagascar, the Abyssinian region of Africa, and the islands to the south of Asia—a circumstance that points strikingly to the lost Afro-Asian continent.

One particular stem of the lemurs was meantime outstripping its fellows in intelligence and other features. If we knew where this took place we might be able to trace the special stimuli in the environment that caused this particular development.   At present the evidence, or lack of evidence, points to the land that foundered in the Indian Ocean sometime in the Tertiary epoch.   The few remains we have of anthropoid apes belong to

France and Germany, and seem to indicate a fresh migration northwards from the tropics. It is, however, unprofitable to discuss the point until further evidence is found. Twenty years ago the problem was more difficult still. There were remains of monkeys and anthropoid apes, but students recognised these as side-lines. In regard to man's development they had only the Eocene fossil lemurs, as likely remote ancestors, and the bones of the Neanderthal man, belonging to at least three million years later—a gulf of time and of organisa-tion over which the bridge of speculation could only be thrown with great risk. Then the famous Java bones were found, and the task was much simplified. A pile was dropped just half-way across the gulf.

When Dr. Dubois brought to Europe from Java in 1894 the four bones—two teeth, a skull-cap, and a thigh bone—he had found, there was an intense conflict of opinion as to their nature. Some authorities said that they were the bones of an abnormal ape, some of an abnormally low man, and the majority that they belonged to a being midway between the two. To-day, casts of the skull of *Pithecanthropus erectus* are given unhesitatingly in our museums (South Kensington, College of Surgeons, etc.) as the first human skull, and there is general agreement that it belonged to a stage midway in development from the anthropoid ape stage (or its equivalent in human evolution) to that of Paleo-lithic man. Both teeth, femur and cranium, are inter-mediate. The thigh was greatly curved, as of an animal beginning to stand more or less erect, and the skull had a capacity midway between that of the highest ape and the lowest prehistoric man. Early Paleolithic man had a cranial capacity of about 1,220 cubic centimetres (in other words, the skull contained that quantity of brain matter): the highest ape has a capacity of about 600.

Pithecanthropus bridges the gulf with a capacity variously estimated at from 900 to 1,000. The bones, therefore, recall a race of beings, squat and stunted in figure, with more or less upright posture, whose prominent jaws and eye-ridges and low foreheads revealed an intelligence as much below that of the lowest known man as it was above that of the highest known ape. It was "the missing link."

The spot in which the bones were found seems to shed some light on the scarcity of the bones of our Tertiary ancestors. Animals of the ape kind are, of course, rarely preserved in the earth. They die on the land, and their frames gradually decay. To be fossilised they must be deposited in suitable material at the bottom of water, and their grave must be brought to the surface by some fortunate accident. The chances are heavily against our finding such bones. For instance, early Paleolithic man lived so long or in such numbers in what we now call France that one single locality (St. Acheul) has yielded 20,000 specimens of his flint implements. The number for the whole of France is so prodigious that many authorities will not admit less than 150,000 years for the life of Paleolithic man alone in France, one of his chief homes. Yet the only bones of him that we find in France are one or two disputable jaw bones, and we have no Paleolithic remains in England, though man lived here for the same period. The chances of finding bones of our much less numerous Tertiary ancestors may be calculated from this. Moreover, the Java bones were found on the edge of the Indian Ocean, and we know that a large amount of land has sunk below the waves of that ocean in the Tertiary epoch. We have to resign ourselves to the thought that this lost continent may have been the centre of human development, and have carried the osseous traces of it

below the waves. The Pithecanthropus bones are mixed
with those of animals of the Pliocene Period, and are
generally referred to the middle of the Tertiary; though
it seems more conformable to later human development
to put them later.

This discovery amply confirmed the view of man's
evolution which had already been taken on the ground of
his vestigial organs, his embryonic development, and his
close anatomical resemblance to the ape. Man and the
anthropoid ape correspond in every organ, apart from
slight differences in the ribs and sex organs. I will take
only one instance from anatomy to show how the
relationship stands. The teeth have a curious evolu-
tionary value. They originated in the mouth of the
primitive shark by a hardening and sharpening of the
prickles on the shagreen plate that lined the mouth.
The crushing of shell-fish, etc., "selected" the prickles
until they developed into teeth, lining the whole of the
palate (as we find them in the young shark). It was
further due to selection that the teeth on the edges of
the jaws (the most useful) were strengthened, and the
others died away. With changes in diet the teeth
degenerated, and our ancestors have been shedding
them along the path of our evolution for ages. The
earliest lemurs had forty-four teeth, the black lemurs
forty, the higher lemurs thirty-six, and we and all the
Old World apes have only thirty-two. But amongst the
lower races and the anthropoid apes we sometimes find
thirty-six teeth, and on the other hand, the higher races
tend to lose four more teeth (the "wisdom-teeth"), and
the same number (twenty-eight) is sometimes found in
the highest apes. We are shedding in fours the teeth of
our remote ancestors, and some equally remote genera-
tion of human beings will probably find itself toothless.

But the more interesting point is to speculate—we

can do no more—on the way in which the lemur evolved into a man during the Tertiary period. How it shed its tail is a trifle: the anthropoid ape also has achieved this. Possibly the fusing of the sacral vertebræ to form a solid support for the more or less upright form led to the degeneration of the rest of the column. The centre of interest is this adoption of an upright posture, for this is probably one of the chief keys to man's higher development. There is little mystery about the adoption of this posture in itself. In a tree-climbing animal it comes not unnaturally. The gibbon stands quite erect, and the other anthropoid apes more or less throw the weight on the hind limbs; while the Pithecanthropus shows that the habit came gradually. In the fierce struggles against the increasing carnivores on the Tertiary plains the horse, antelope, etc., found their safety in speed. The ape took to the trees, and the strength and tenacity of the new-born baby's fingers recall our own arboreal ancestor. The baby can support itself by hanging on to a stick. Dr. Robinson found that some babies under a month old could support themselves in this way for more than two minutes.

It is thought by many authorities that this tree-climbing habit, by leading gradually to the adoption of an upright posture, was the chief determining agency in the initial development of man's intelligence. Any good work on physiology (I have Kirk's before me) will show that the hand-centre in the brain verges upon the region which is now known to be instrumental in acts of reason. Hence any important advance in the use of the fore-extremity will develop the hand-centre in the brain, and may stimulate the neighbouring intelligence-centre. Now the adoption of the upright posture involved a change of this character. Instead of a passive support to the body, the fore-foot becomes a hand with prehensile

fingers, and is adapted to a number of functions. Even the ape throws nuts at its enemy and breaks branches of the tree to fight with. Our early Tertiary ancestor, taking to the trees in self-defence (a habit for which his marsupial ancestry prepared him), thus changed the function of his fore-extremity, and may, through the hand-centre, have given that initial stimulus to mind-development which put him on the higher way. Once he had a slightly higher degree of intelligence to that of his animal rivals, we may trust natural selection to develop so valuable a distinction.

This speculation is plausible enough, but it is well to remember that it is only a provisional suggestion. No one will question, seeing the habits of all apes, that our early ancestor was arboreal, but the physiology of the brain is not yet clear enough to warrant us in pressing the rest of the speculation. On Mendelist principles it might be suggested that there was an abrupt rise, in some great crisis, in the quality of the brain. I prefer to suggest that, after allowing for a probably considerable influence of the adoption of the upright posture, we should look to the known action of natural selection for the explanation. Thus was the intelligence of the ant or the bee evolved. Intelligence is so important a weapon, where there is neither great speed nor great strength, that it is by no means wonderful if it was " selected " in our early lemur ancestor. Why it was more selected in our branch of the anthropoids than in the others is no more mysterious than the selection of the ant or the bee among the insects. But the confusion generally comes of an exaggerated idea of the intelligence of early man, and the next chapter will put us right on that point.

CHAPTER VII

THE ADVANCE OF PREHISTORIC HUMANITY

WHEN, in following the story of evolution, we arrive at the stage in which human faculty definitely appears, we find ourselves on much firmer ground. Man has been defined as the animal that makes and uses tools. For ages that was his main distinction from many of his animal neighbours, and it has had a fortunate result for modern science. No doubt the first weapon employed by the most primitive of our human ancestors was a convenient piece broken from a tree, as we find in the ape. Such weapons decayed like their users, and have left no trace. Stone-throwing would be the next device of the small and ungainly human in its conflicts with its fellows, and especially in defence against its larger enemies. Presently the dull wit notices that a sharp stone is more effective than a round one, and the practice begins of chipping the stones. At last a definite hatchet-edge and point is evolved, and from this form we can trace the growth of the weapon up to the flashing axe of the warrior of the iron age. It is a plain story of the growth of human intelligence, beginning below the level of the lowest savage of our time and rising gradually to the heights of modern science, art, and industry.

The home of the ape-men of some hundreds of thousands of years—if not a good million—years ago was the south of Asia. Curiously enough the next traces of man that are claimed with a good degree of confidence are found in England. Britain and even Ireland were still united to the continent well into the Pleistocene

period, and there is ample interval between the Java
man and the "Eolithic" man to allow so great a
migration.   But I must inform the reader that these
"eoliths" (early stones) are challenged by many
authorities, especially on the continent.   From the
nature of the case, the earliest flint-chipping is so crude
and elementary that it is difficult to distinguish them
from accidentally chipped stones.   Large numbers of
what are called "eoliths" may very well be flints that
have been chipped in the friction of the torrent bed, but
at the same time a number are so striking in their
contour that Sir Joseph Prestwich, Lord Avebury, Sir
E. Ray Lancaster, and other high authorities, declare
them to be the handiwork of a very primitive man.
Sir J. Evans is always quoted as a weighty opponent,
but at least we find him saying (in 1902) that Harrison's
"numerous and important discoveries" had "done
much to revolutionise our ideas as to the age and char-
acter of the drift deposits capping the chalk Downs in
west Kent."   If they are genuine, they point (as Sir J.
Prestwich showed) to the existence of a very lowly type
of human being in this part of the world several hundred
thousand years ago.   They are now claimed for other
parts of England, and for Egypt, India, and other
countries.

Passing by these still disputed traces, we come to the
implements and remains of Paleolithic (early stone) man.
The evidence now becomes so abundant, and so plainly
tells the story of the evolution of humanity, that we
could dispense altogether with the Java man and the
eoliths.   This earliest race of Paleolithic men has been
called the Neanderthal race, because the first and most
complete remains were found at Neanderthal (near
Düsseldorf in Germany).   It roamed over what are
now Austria, Germany, France, Belgium, Spain, Italy,

Switzerland, and England, and has left literally millions of its flint (or other hard stone) implements on the floor of Europe—a floor that is now buried sometimes forty feet below the actual surface.   Four more or less complete skeletons (Neanderthal, Spy, and Krapina), and a few lower jaws and fragments of skull suffice to give us a good idea what this very early European was like. The skull and jaws and thighs go back a long way toward the ape type, though—as we should expect—not as far as the Java remains.   The beetling brows, very low receding forehead, and bulging jaws show a lower type of savage than the Australian native, and the cranial capacity is very low (about 1,200 cubic centimetres). The thigh is appreciably curved.

Here we have just the type of human being that our theory of the evolution of man suggested.   On that theory our ancestor would have arrived at something like the gibbon type of anthropoid ape by the middle of the Tertiary epoch (at least two million years ago), and if we found remains of that phase we could do no more than class them as anthropoid apes.   By the end of the Tertiary (a million years ago) he would have passed just beyond the ape level, and there precisely we find the ape man of Java—a squat, powerful, probably hairy being, about five feet high, with brutal jaws and forehead.   If we accept the eoliths, he arrived—let us say half a million years ago—at the stage of chipping flints about as crudely as a small schoolboy would.   Then comes the Neanderthal race; let me put it provisionally at 200,000 years ago, for reasons we shall see presently. He is still far below the level of the existing savage, and is a stout, stumpy, muscular being, a little over five feet high, without home, grave, or clothing, without arrows or hafted weapons, roughly chipping his flints to a cutting edge and point, beginning to live in small social groups,

A RESTORATION OF THE NEANDERTHAL MAN

This picture is a retouched photograph taken of a model made by Guernsey Mitchell according to the instructions of Professor Henry A. Ward of Chicago.

but apparently without language or religion, and wandering naked along the banks of the broad rivers. What strikes one most forcibly is the *slowness* with which his intelligence has developed during two million years.

This early race is so interesting that I will dwell on it a little more fully, before we pass on to the more swiftly moving panorama of later development. I have handled the chief bones of its skeleton, and seen the force of the conclusions that Dr. Munro, Worthington Smith, Mortillet, Hoernes, and other constructive writers draw from them. The low degree of intelligence is admitted by all, and would be established by the poverty of early Paleolithic man's handiwork if we had not half a dozen skulls to show it. That he was naked I infer from a circumstance which seems to be generally overlooked. Long afterwards, at the close of the Paleolithic period, this race developed an artistic faculty, and has left us some scores of drawings on bone, horn, etc. Amongst these are a few human figures, and these are always nude and covered with indications of a hairy coat. It is probable that clothing was being worn at this time (the cave-man period), but if we have a conspicuous hairy coat and a commonly nude condition after three-fourths of the history of the race has run, what should we expect at the beginning? That Neanderthal man had no religion is inferred from the complete absence of burial and of religious symbols until the Neolithic period. And that language was yet undeveloped is a fair inference from the smallness of the tubercle to which the chief tongue-muscle was attached in the lower jaw. The hypoglossal muscle, which we use so much in articulate speech, was evidently poorly developed.

The time when this naked race of lowly savages wandered about the banks of our rivers, and penetrated

to the north of England, cannot yet be determined.
Few authorities think it can have been less than
100,000 years ago, and some put it at 700,000.
It seems to me that Mortillet (*Le Pré-historique*)
has made the most careful calculation, and he puts
it at a quarter of a million years ago. That
200,000 years is a moderate estimate will be seen
from these facts. In France (at Chelles, for instance),
we find the floor of Neanderthal France forty feet below
the present surface. In England this early man was a
contemporary of the rhinoceros, hippopotamus, sabre-
toothed tiger (or lion-tiger), hyena, mammoth, and other
strange forms. He wandered over on foot before the
German Ocean cut off England from the continent; and
there is good reason to think that the Thames ran in a
broad swampy bed several miles wide when he basked in
the sun on its gravelled shore, and that the whole
valley on which London is built has been cut out since.

The closer we bring Paleolithic man to our own time,
the more unintelligible we make the long evolution from
the ape stage, but the question is obscure and not very
important, so we may leave it to future archæologists.
Taking the whole history of humanity, from the appear-
ance of Paleolithic man, as 200,000 years, we must
assign three-fourths of this to the Paleolithic age.
Progress was still inconceivably slow, judged by our
modern standards. After a time we get slightly
improved skulls (Chancelade, Sordes, Laugerie Basse,
Brünn, etc.), and the chipping of the flints becomes
much finer. The climate of Europe becomes colder
once more—probably owing to a fresh extension of the
ice sheet in the north—the hippopotamus and tiger and
hyena retreat south, and man begins to live in rock
shelters and caves. It was probably about this time
that he discovered the use of fire. As the earliest fire-

making implements (in Neolithic graves) are flint and iron pyrites, I infer that he made the discovery by knocking sparks out of pieces of iron ore, of which he was trying to make implements; but it is generally conjectured that he first obtained it by the common savage practice of rubbing sticks. We get also the first indications of clothing. Flint scrapers are found, which seem to have been used for scraping the insides of skins. Bone needles, skilfully rounded and pierced with flint borers, are found in the French caves, and even buttons soon occur. For thread he must have used the sinews of the reindeer that spread over the icy face of Europe as far as the Pyrenees. Moreover, the artist appears for the first time, and some of his scratchings on bone and stone show a considerable skill in the delineation of form. He also made fair progress in small sculpture, and began to adorn the walls of his cavern with coloured figures.

Apart, however, from this curious artistic development, which was nearly confined to France and soon became quite extinct again, the progress made in the long Paleolithic period was slight. The stone weapons and tools have a finer finish and much greater variety, but during those 150,000 years it did not occur to any human being that a far better edge could be obtained (on quartz, basalt, etc.) by grinding and polishing. The only home is the natural cavern, and there is as yet no pottery, no trace of a rudimentary husbandry, and no kind of weaving. The dead seem never to have been buried, there are no characters that could be construed as a crude beginning of writing, and no symbols or marks that we have serious reason to regard as religious. The Franco-Spanish caverns, with their long stretches of ornamentation and the thick rubbish of weapon factories, bone heaps, etc., indicate that men now lived in large

groups, but the social form we can only conjecture to
have been an extension of the family circle.   What used
to be called the "commander's batons," that are found
in some caves, were most probably implements for
sharpening pointed weapons.

The earlier three-fourths of the history of humanity
(dating from Neanderthal) shows therefore a very slow
and gradual evolution of intelligence and institutions.
Dr. Russel Wallace and Dr. St. George Mivart, and
some of the older anthropologists used to say that though
man's frame was evolved from that of the lemur, his
higher powers had not been so developed.   Clearly this
is quite at variance with the abundant evidence we now
have.   All the remains and works of early man fit at
once in the scheme of gradual evolution.   In fact, it is
the slowness of the evolution that chiefly surprises one
on a review of the whole evidence.

However, this Paleolithic race is now somewhat
brusquely superseded by the Neolithic (New Stone) men
that overrun Europe with polished stone weapons, bows
and arrows, tombs and monuments, and rough weaving,
pottery, and agriculture.   In older works on the subject
one reads of an unintelligible chasm separating the two
races, and the Neolithic men seem to spring up as if by
magic.   In England and other countries this is a fair
statement.   The old race died out—whether by ice age,
plague, or inundation we cannot say—and the new came
on with a much higher culture.   But we must remember
that men were developing during this whole period in the
north of Africa and the south-east of Asia, and we have
good reason to look there for the connection.   The
successive invasion from the south of higher types is one
of the familiar processes in the biological record, which
has been curiously reversed in our time.   We have, in
fact, good ground in the character of some of the

ıkeletons found on the Riviera and in Switzerland to
think that the Neolithic invaders came from North Africa.
Probably bridges of land still existed then across the
Mediterranean.   Even in southern France and Austria
the transition can be fairly traced.

Hence we have no reason whatever to depart from
evolutionary lines, though the origin of many of the new
practices and institutions is obscure.   The stone
implements are clearly only an improvement on the
older ones, but the origin of their crude clay pottery,
rough weaving, burial of the dead, agriculture, and use
of domestic animals, can only be dimly conjectured.
Possibly a culinary practice of covering the joint of
horse or reindeer with clay, to prevent burning, gave the
first idea of making clay vessels, and weaving may have
begun with the twisting of animal nerves and sinews.
The fact is that the human family now has the
rudiments of civilisation, and spreads as far north as
Scotland and Scandinavia.   Villages are erected, with
daub and wattle huts, one or two species of small oxen
and pigs, and several kinds of corn and millet.   Spindle
whorls are found in their ruins, and quorns for grinding
corn, and even rough bits of woven fabric.   The
mixture of races begins to perplex us, and the modern
study of skulls from the ancient tombs has by no means
established the lines of early racial evolution.

Over Europe two main races, the long-headed
(dolichocephalous) and short or round-headed (brachy-
cephalous), are found to prevail.   The long and round
barrows of England fitly represent each type.   An
African type seems to appear before the end of the
Paleolithic, and it is a very general opinion that the
stone monument builders came from the south of Asia
along the shores of the Mediterranean, and up through
Spain and France to Britain, and across Europe to

Scandinavia.   One branch settled in Switzerland, and
erected large villages on piles in the great lakes.   In the
mud of some of these lakes that have been drained we
find a most remarkable collection of relics of this race.
Just as the later Romans took refuge on the islands of
Como from the northern barbarians, these Neolithic
men built over the water (as is done in New Guinea and
Malaysia to-day, or as the medieval Irishman fled to his
crannage from the rent collector).   Floods and fires
destroyed them time after time, and we fish up to-day
the materials with which we reconstruct the life of
Neolithic man.

As we draw near to historic times the use of metal
supersedes stone.   Once more we have to turn south-
ward for the developing centre.   The more we learn, the
more clear it is that the stretch of territory from
Morocco to Borneo has been remarkably fertile in
advances.   Europe received from that line (or below it)
its first mammals, first apes and anthropoids, first men,
first Neolithic men, and first civilisation.   It is in Egypt
that we find the earliest use of metal—bronze—about
4000 years B.C.   Copper, which is so much softer and
is found in nature, was probably the first metal to be
used, and copper implements are found.   But it seems
to have been quickly discovered that the softer metal
could be hardened with a mixture of tin, and bronze
spread through Europe.   By about 1800 B.C. it super-
seded stone (generally) in Britain and Scandinavia.
Some writers are unwilling to grant Egypt the credit of
inventing it, but there at all events we find its earliest
development.   Gold also, a conspicuous but rare metal,
may have been worked very early in the metal age;
and there is reason to think that in Egypt iron was
known almost as early as bronze, and it was much

worked in Italy and Switzerland in the millennium
before Christ.

We are now well within the historical period, and must
not pursue the inquiry further. To attempt to show in
detail the evolution of the arts, sciences, religions, and
social and political institutions that make up civilisation,
is far beyond the scope of this little work. I will
conclude with a few pages on the very obscure question
of the origin of races and of languages.

The " cradle of the human race " is no longer sought
on the uplands of Central Asia, wherever it may have
been. We have seen that the evidence is much too
scanty to justify any attempt to locate it, but the few
indications we have point toward the lost land south of
India. A dispersal from that point—supposing that the
land-connection still existed with Asia, Africa, and
Australia—would be easily understood. One branch
travelled north-eastward, and formed the great stock of
the Mongolian and cognate races, and sent a branch
across the northern bridge into America, to flower at
length into the Mexican and Peruvian civilisations. The
centre of another group is India, round which we find
numerous fragments of the primitive peoples. A third
stream flows into Africa, and stagnates in the black races
south of the Equator. So far the imagination travels
with ease, but " the Mediterranean race," or the group
of races in South-east Asia, North Africa, and Europe,
offers a very entangled problem.

The older theory that the " Aryans " overflowed from
Asia into Persia and Europe is generally rejected, and a
dozen theories dispute its place. It is easy to connect
the languages of the old Hindoos, Persians, Greeks,
Romans, Teutons, etc., but languages are often borrowed
or imposed, and we have no guarantee of the connection
of the races. There is still a disposition to see in the

Basques, with their curious language and old customs, and the Pict element in North-east Scotland relics of the early Neolithic population of Europe. But where the later race or races came from is not clear. Some say they were developed in East Europe, some bring them still from Asia (though not as a civilising race), and some from North Africa. It seems to me that the evidence points to a pressure from Asia, sending movements through Egypt and North Africa, through the Caucasus and Asia Minor, into Europe. But the question is too unsettled to pursue here.

As far as Britain is concerned there is more agreement, though still scanty evidence. The Paleolithic race, that had wandered on foot from France, and spread to Yorkshire, entirely died out. A more or less glacial period may have driven them south, and in fact we know that in one of these cold periods England sank below the level of the waves. Arctic cells are found high up on the flanks of Welsh mountains. The next, or Neolithic invaders, are regarded by Windle and Boyd-Dawkins and other writers on the subject as related to the Iberians of early Spain and bringing the Druidic cult and agriculture into England. About or after 2000 B.C. they had to face two Celtic invasions from the continent, with bronze arms. Whether the Goidels (Gaels) or Brythons (Britons) came first is not wholly agreed, but the distribution of races favours the former. The stone-using natives fled north before the bronze-using Celts, and many have identified them with the Picti (or "painted men") of the early Roman writers, in the far north. The Brythons in turn drove the Goidels to the north (Scotland) and the west (Ireland), and possessed the land till the advent of the Romans. Cæsar is responsible for an impression that our British ancestors clothed themselves in paint, and lived on acorns, when the

Romans first brought them civilisation. In point of fact, a very promising civilisation was already developing. Bronze weapons and gold ornaments of skilful workmanship are found amongst the remains, and Stonehenge (built about 1800 or 1700 B.C. on the site of an earlier temple) survives to remind us of the Druidic cult with its beginnings of science and education. The last pre-Roman phase, the "iron age," saw a steadily developing civilisation. How the Roman hand was withdrawn, and Anglo-Saxons and Danes played the vandal, and Norman blood brought a fresh stimulus, is a familiar page in the evolution of England.

The question of the evolution of languages is just as involved as that of races. A great deal of speculation has been published on the unity of languages, but it must be admitted that the problem is yet unsolved. The so-called Aryan, or Indo-European, languages have been brought together with a good degree of confidence. The Indic (Sanscrit), Iranic (Persian, Afghan, etc.), Anatolic (Armenian, Scythian, Phrygian), Italic (Latin, Umbrian, etc.), Greek, Celtic (Welsh, Breton, Cornish, Erse, Manx, and Gaelic), Teutonic (German, English, Scandinavian, etc.), and Balto-Slav (Lithuanian, Lettic, Slav, etc.), are now generally agreed to be developments of one older tongue. The home of this earlier language is now located by most philologists on the plains to the north of the Carpathian Mountains, but there is not the older tendency to conclude that some primitive Indo-European race lived at this spot, and scattered into the localities where we now find the daughter tongues. Race and language are carefully separated in the modern attempt to trace origins and migrations. Beyond this group there is no agreement. Efforts have been made to connect with it the Mongolian, Semitic, and other groups, but the result has not been generally

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satisfactory; while a large number of languages and
dialects defy the comparative philologists. Nor is there
much greater agreement in theories of the origin of
speech generally. It is merely generally felt that
language was gradually evolved when Paleolithic men
came to live in social groups, by a slow process of
attaching a definite and conventional meaning to sounds
that were at first natural and spontaneous.

Of the growth of written language we have somewhat
better traces, as it falls later. No one now doubts that
it began with the depicting of objects, as in the old
Chinese and Egyptian hieroglyphs. In Chinese each
word is a root, and is expressed by one character.
Comparing the most ancient with the modern, we find
that the character was originally a picture or symbol of
the object. Egyption hieroglyphs are obvious pictures,
and here we seem to find the picture degenerating into a
phonetic element, and coming to stand for the first part
of the sound (the first "letter") in the name of the
object. Babylonian cuneiform characters show a similar
degeneration to the Chinese, from rough pictures made
with the chisel in the clay to conventional signs. Much
labour has been expended in tracing the European
alphabet to the older hieroglyphs, but we must leave the
subject to special treatises.

CHAPTER VIII

A FORECAST OF THE END

THE reader will be disposed to pause here for a moment in our breathless race through the avenues of time and sum up our discoveries. We have in the preceding five chapters covered a period of development that may well have occupied a thousand million years or more. That we have done so very superficially is no reproach to so slight an essay as this. It has been sought only to trace the broad lines of the evolution of our world and its inhabitants. Almost each page of this essay could be expanded into a volume with the aid of the many sciences that co-operate in piecing the story together. But there is a discipline and a certain fund of instruction in making this swift and general survey of the entire panorama. We enlarge the mental frame in which we may set the various particular studies that may occupy our closer attention. We get a fine sense of perspective, in more matters than scientific study.

So far we have passed rapidly along the series of changes that have led up to our own appearance. In a vast universe, in which countless worlds are growing and dying, just like the million inhabitants of a great city, we single out a widely diffused cloud of matter that is beginning to condense into our solar system. We see it fling out its fiery arms or fragments, and then gather into the great incandescent ball of the sun. We see one of these cast-off arms or masses, weighing 6,000 million billion tons, round slowly into a smaller incandescent ball, cool down, and form a hard crust round

its surface. We watch the dense shell of steam condense into water, and clothe nearly its whole surface. We mark the tiny specks of living matter that appear in the water, cluster together, grow into little elongated bodies with sensitive heads and rows of oars at the side. We observe some of them curl up inside protective shells, and others break up into armoured joints and creep on to the land, and develop wings and fly in the atmosphere. We see the green mantle creeping over the rising continents, and the fish taking to the land, and colossal reptiles sprawling or leaping over it, and taking wing in turn into the clearer air. We note the growing coldness, and the paralysis of the great reptiles, and the spread of smaller creatures with quicker brains and better blood. We fasten on one of these insect-pursuing beings, and see its intelligence sharpen in the fight with stronger or swifter competitors, and its face slowly turn toward the heavens. And we see that face gradually lose its bestiality in the care of young and the growth of social life, shine with increasing intelligence as it realises its power, and at last set up homes and ideals and marvellous constructions under the sunlight.

So some remote and detached spectator, with a large sense of time, would view the panorama of evolution as it has hitherto unrolled. What is depicted on the rest of the canvas to be unrolled to the eyes of the future? How much we would give to know! It is a strictly scientific feeling that the future holds changes more vast and wonderful than any that have preceded. Evolution is going on in the world more rapidly than ever. The pace increases in every century. Social and political and ecclesiastical institutions are evolving. Science and industry and commerce and morality— schools and homes and cities and workshops and theatres and vehicles—all are leaving a crude past behind

and advancing up heights that are wreathed in mist. Evolution is writ large over every modern city and nearly everything in it. But we cannot open so vast a subject at the close of this short survey, nor can we put great faith in predictions of the future evolution of the human family. That there will be a great evolution is clear, not only from the present pace of progress, but from the fact that the earth is now ruled by a colony of self-conscious beings. The vision that is lit up in the human mind, and the new power that resides in the human will, promise an evolution far greater than any that could be accomplished by the unconscious forces of nature.

Leaving now this uncertain and fateful future evolution of humanity I turn again, in conclusion, to the broad theatre in which the drama is being played. No one now doubts that that drama will sooner or later be brought to a close. Everything in the universe " has its day and ceases to be," and our little world has plenty of evidence of mortality. Indeed we may carry a step further our comparison of our world to an individual living with myriads of others, of all ages, in the common-wealth of the stellar system. Like the commonwealth of men, the universe has its cradles, its births, its young, middle-aged, and old, and its entombed dead. Like any living man in a great city—we may almost say—our world may conceivably meet its end either by internal malady, by accident in the streets of space, or by slow and senile loss of vitality. Earthquakes and volcanoes remind us of its internal maladies, comets, meteorites, new stars, and dark nebulæ raise the question of possible collision, and, if premature end by malady or accident be averted, the extinction of the heart of our solar system gives us absolute certainty of the final termination.

In regard to the first conceivable possibility, death

from internal convulsions, the earth has little serious
ground for apprehension.   The cause of both earth-
quakes and volcanoes is still obscure, but it is at least
connected with the intense heat and pressure below
the crust.   Probably forty to fifty miles of solid rock
form the earth's crust.   This is a mere egg-shell in
comparison with the 8,000 miles of molten matter that
is confined and compressed by it, and imagination can
easily depict this thin envelope yielding to the pressure
below and allowing floods of molten lava to overflow the
cities of men.   The moon is sometimes referred to as the
skeleton at our feast.   A dead extinct world (save for
some probable traces of vegetation) it seems to say to
the earth: "Such as I am, will you also be."   Its visible
face is studded with some 200,000 crater-like formations
that seem to tell of an appalling outpouring of its molten
interior upon the surface in some by-gone age.   Will the
earth sustain some similar epidemic of eruptions in an
age to come?

The point need not distress us.   The smaller size of
the moon really involves differences of a very radical
character.   It is probable that the moon has been too
small to retain, by gravitation, an atmosphere round it,
and thus been exposed to a fierce bombardment from the
heavier meteorites in space.   There are astronomers
who regard its so-called volcanoes as merely the splashes
of large meteorites impinging and liquefying on its face.
In any case it is very doubtful if these round formations
are volcanic craters.   Some of them are sixty miles or
more in diameter and only 10,000 to 20,000 feet deep.
This is a totally different structure from what we know
as a volcano.   A distinguished German astronomer,
Fauth, who has made a life-study of the moon, believes
that its face is one mass of ice, and the "craters" are
pits formed by the breaking through of the warmer

ocean beneath. On the other hand, some of our English astronomers still regard them as real volcanoes, and possibly the sources that have shot out into space great numbers of wandering blocks of stone and metal. I have seen Vesuvius shoot up white-hot rocks weighing sixty tons, as if they were pebbles, and can appreciate the point; but the whole question has still to be discussed with great reserve, and we must draw no inferences.

In point of fact, our volcanoes are rather in the nature of safety-valves. As is well known, they lie largely along two lines on either side of the Pacific, and seem to indicate weaker seams or fissures in the crust. Through these vents—unhappy as it is for the local inhabitants—the pressure below is occasionally eased by the discharge of gases and molten rock. Earthquakes are frequent along the same lines of weakness. Some astronomers have gone so far as to suggest that the deep bed of the Pacific Ocean represents the spot from which the lunar material was torn ages ago; though it is more likely that the earth was then plastic enough to resume its shape. At all events, the geological record suggests that volcanic activity is decreasing as the earth grows older. It must have been incessant in the early stages, and there were great outbreaks in connection with the rise of mountains at the periods we described. Quite late in the Quaternary epoch the face of France was illumined by the glare of volcanoes. There is no ground for anticipating any great development of volcanic or seismic activity.

As to our second alternative, collision, there is just as little ground for anticipation, but a much wider margin for accident. One or two writers have lately, and more or less playfully, suggested the possibility of collision with a comet. The feelings of men in regard to comets

have undergone remarkable changes. In the Middle
Ages they were dreaded as sources of every kind of
pestilence and tragedy. Nineteenth-century astronomy
calmed the fear—it broke out in Russia and Mexico less
than fifty years ago—and led to something like a
contempt for even the long-tailed comets. The tail
might be 100 million miles long, and was often over
fifty, it explained, but it was thinner than the thinnest
breath of air. Some said even that the whole material
of a hundred-million-mile comet might, if properly com-
pressed, be packed in a railway truck. One may still say
that of the tail of a comet, but its head consists of a swarm
of meteorites, sometimes several thousand miles in width,
the colliding elements of which are raised to white heat,
and give off the vapour which is shot out in a tail by the
action of the sun. Through this tail the earth may pass
—and has passed—with complete indifference. And
even if we ran into the "head," or the close swarm of
large meteorites, the earth's great torpedo-net (its
atmosphere) could be trusted to protect it. We should
be treated to a brilliant display of shooting-stars, and
most probably suffer no damage.

Flammarion, in a little work called *La fin du monde*,
has indulged his vivacious imagination on the subject,
and conceived the earth as running through a comet-tail
consisting of gases that poison the atmosphere and
nearly destroy the human race. Mr. Wells has turned
the idea round, and made the comet's tail act in such a
way on the atmosphere as to convert the whole human
race, physically, into angels and Socialists within the
space of a few hours. These are merely playful
manipulations of the very remote astronomical possibility
of a comet coming along that would interfere with the
oxygen in our atmosphere. The whole question is well
discussed in a little work (*Weltuntergang*) by the able
German astronomer, Meyer.

On the other hand, any speculative student who does not care to sacrifice altogether these harrowing possibilities may be assured that we really have no guarantee of the stability of our system for a single year. All the stars are moving rapidly, but they seem generally to move in considerate orbits and keep their distances from each other. The nearest to us is twenty-five billion miles away. Now that we know of the existence of dark stars, no one can say how much nearer we are to one of these. Most probably the dark stars are regulated in their paths by gravitation, like the visible ones, but the paths of the stars are still very obscure, and we saw that some astronomers believe in collisions, or close and mischievous approaches. In fine, there are the dark nebulæ and heavy swarms of meteorites which very many astronomers regard as the causes of the conflagrations that are witnessed occasionally in the heavens. No astronomer could give us any security whatever that we *may* not at any time plunge into one of these, as our sun bears us through space at a speed of twelve miles per second. Those who revel in lurid possibilities may dwell on this. For most of us it is enough that our solar system has escaped such contingencies for some hundreds of millions of years, and may be trusted to do so for the few million years that still lie before humanity.

I will not linger over the further possibilities that have been suggested by ingenious writers. Geologists have pointed out that the sea and rain are wearing away the land, and conjured up visions of a time when the ocean may once again flow over the entire earth. No doubt that would be the natural line of development in an indefinite time, but it happens that the power of man to protect his land is equally developing.

Physicists point out that the gases of our atmosphere

are slowly escaping the earth's gravitation and passing into space. We may regard the slight escape without concern. The evolutionist will turn rather to the astronomer, and ask him what lesson he learns for the future from the other contents of the universe. And from the astronomer we learn that, beyond any question, life will come to an end on our planet by the extinction of the sun.

Our chapter on the birth of our solar system has, in fact, fully prepared us for its death. Our earth was once a small sun, glittering brilliantly in space (if there were any to see it). As surely as it was extinguished, and from the same causes, the parent sun will grow dark. When we examine the sun through a (protected) telescope, we find its surface covered with a network of dark streaks, terminating here and there in the black patches we call "sun-spots." Spectroscopic investigation shows that these spots are oceans of cooler vapour lying on the brilliant bed of incandescent metal. It rains liquid metal on the sun. From the appalling ocean of the photosphere the vapours of molten metals rise high up with the atmosphere, cool and fall again upon the surface, and run together into lakes and oceans. Black as the "spot" seems, it is really brighter than white-hot iron, and is merely darkened by the contrast of the dazzling photosphere. But the process will no more go on for ever than it did in the case of the earth or Jupiter, or any of the dead or dying suns in the heavens. No matter what the sun be composed of it cannot give out heat indefinitely. The cold of space will gain on it in time. The cooler vapours will gather thicker over its photosphere, and men will look up to a red and failing luminary above their heads.

We saw that the stars are now classified according to their spectra, and illustrate the whole process of the

birth and death of worlds. There is still a good deal of divergence in the different systems of classification (as in zoology), but the main line of evolution is clear. From white stars at the highest temperature we descend slowly to blood-red stars with choking fires. The intermediate stages are difficult to deal with, as they may be either rising or falling. But there are unmistakable classes of dark red stars, in which the broad dark absorbent lines of the spectrum show the deepening of the cooler vaporous envelope round the star. Red variable stars seem to carry the story a step further. Apart from cases of variable stars in which a star probably passes periodically through a swarm of meteors, there seem to be others in which the molten mass is making its last struggle with the dark envelope that is closing on it, and bursting out occasionally with fiery energy. Beyond this are the almost dark, and then entirely dark, companions of some of the stars. It is not difficult to follow the evolution. As the energy of the central mass decreases, the cooler vapour forms a deeper layer round it until at last the whole sinks to a mass of dull red-hot metal and gas. The vapours grow colder, and run to liquid. Colder still, the formation of solid matter sets in, and there will be the long struggle of the first formation of crust. In the end the comparatively exhausted sun can resist no further, and the band of rock encircles it, only to be burst by great volcanic rushes through its crevices.

That this is the future evolution of our sun is taught us beyond question by the whole contents of astronomy and the early chapters of geology, to say nothing of physical principles. Slowly, in some future age, as humanity builds its glittering towers in the happier cities to come, the life-giving energy of the sun will fail. By what mechanical devices the failure of light and

heat will be combatted for a time it is idle to conjecture. The humanity of that time will be more different from us than we are from our lemur ancestor of the Eocene period. But the heart of the system dies when the sun ceases to give sufficient light and heat, and no one can doubt that all life will perish on the planets. Whether Jupiter and Saturn will by that time have developed far enough to support life we may doubt; certainly the story of life cannot run far on those as yet immature planets. In the case of Mars we cannot even regard the canals as a sure proof of the presence of intelligence, but—in spite of Dr. Wallace's able but inspired speculations—it seems that the conditions of life are realised on Mars, and on general principles it is reasonable to assume that the evolution of some type or other of life has run there to even greater heights than on earth. The question of Venus is more difficult, but it certainly cannot be said that we must exclude life of any type from it. These, however, are as yet idle speculations. Whatever populations there be on the planets of our solar system are surely doomed when the sun goes down for ever.

When will these things be? Let us say, quite candidly, that we have not the slightest idea, but it is not likely to be less than many million years. On the older theory, that the heat of the sun was created almost entirely by its condensation, the physicist had some ground on which to approach the problem. Assuming that our sun had passed its prime of life, it was calculated that it would last for between ten and fifteen million years yet. But it is not admitted by all astronomers that our sun *is* in its decline, and the period allotted would have to be enlarged. Now, however, the discovery of radium enlarges it still further, and makes it quite indefinite. We do not know what radium there

is, or what sources of radium there may be, in the sun; and it is absolutely futile to say how many million years may have to be added to the original calculation. There is time for humanity to reach any height it may dream of.

We must be content that science can, after less than a century of real growth, lift us to a point from which we survey so wonderful a panorama. But does it ring down the curtain quite finally on our solar system with the death of the sun? Does it give us any glimpse into the darkness beyond? It tells that in the course of ages our planets, since they circle not in an empty void but in a resisting medium, will one by one return to the parent body. It follows this dark and cold body, traversing space at the rate of twelve miles a second, and knows that in millions of years our dead sun may meet one of those accidents that are illustrated by our new stars. It may plunge into dense and prolonged swarms of great meteorites, or through a nebula; it may approach so close to another colossal body that its crust may be torn off, and the molten interior rush out; it may actually collide with another star, many think. In such event its enormous energy of motion will be converted into heat, and liquefy or vaporise the whole mass. In other words, there may be a great resurrection, a return to the nebula, and a fresh run of the story *da capo*. In any case the story will be going on in other parts of space. An old symbol of eternity was the serpent with its tail in its mouth. It is the symbol of cosmic evolution.

THE END.

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